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TOPOGRAPHIC DEVELOPMENT

OF THE

KLAMATH MOUNTAINS

BY

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TOPOGRAPHIC DEVELOPMENT OF THE KLAMATH MOUNTAINS.

By Joseph S. Diller.

INTRODUCTION.

The observations on which this paper is based were begun in 1889 during a trip across the Coast Range from the Sacramento Valley to the mouth of Eel River in California,[1] and have been continued since then at intervals, throughout the limits of the Klamath Mountains, from the fortieth parallel in California to the Coquille River in Oregon. In the summer of 1900 several months were spent along the coast from Port Orford in Oregon to Clear Lake in California, and thence northward by way of Stony Creek on the eastern slope of the Coast Range to Bully Choop. Since then a trip has been made, chiefly on horseback, from San Francisco northward through the Coast Range, Klamath Mountains, and Cascade Range by way of Round Valley, Eel River, and the valley of the Klåmath, with numerous side excursions from the general route.

The topographic development of the coastal region of California from San Francisco to Humboldt Bay has been graphically described in an excellent paper by Prof. A. C. Lawson,[2] whose general conclusions are in many respects essentially the same as those of this paper, which gives them a wider and more detailed application.

THE KLAMATH MOUNTAINS.

The Klamath Mountains (Pl. I), although a portion of the Coast Range lying between the fortieth and forty-third parallels of California and Oregon, are most conveniently treated as if independent. They are composed largely of sedimentary and igneous rocks similar to those of the Sierra Nevada, but contain also some of Cretaceous age. At the north they are easily separated from the Coast Range of Oregon, which begins among the Rogue River Mountains and is made up chiefly of Eocene sediments.

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[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 408.

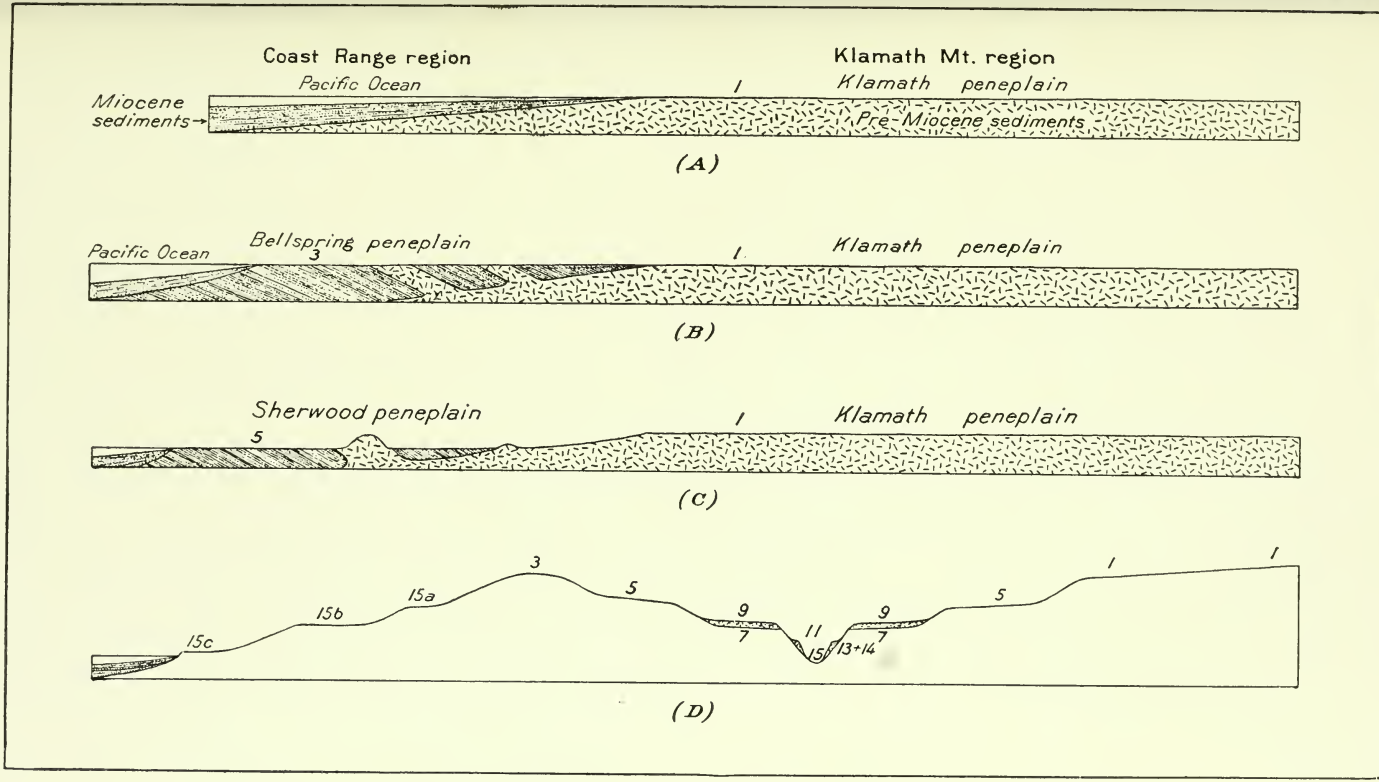
[2] The geomorphogeny of the coast of northern California: Bull. Dept. Geol., Univ. California, Vol. I, pp. 241-272.

At the south the Klamath Mountains can not be distinguished from the Coast Range of California on the same basis, for the Eocene does not occur in the northern part of that State. Other formations, however, taken in connection with the drainage, afford a convenient means of distinction, and the South Fork of Trinity River may be considered as marking approximately their boundary. In the Klamath Mountains the drainage is transverse and irregular, owing in large measure to diversity of structure and composition, but in the adjacent portion of the Coast Range in California, which is made up almost wholly of crushed sandstones and shales, with subordinate masses of igneous rocks and glaucophane-schist, it is in general parallel to the strike of the rocks.

There is thus developed a remarkable parallelism of the principal streams, not only to one another, but to the general trend of the coast (about N. 27° W.) from San Francisco to Cape Mendocino. The easternmost stream of the group is the South Fork of Trinity River from its head to the mouth of the Klamath. On the west lie the Mattole and the South Fork of Eel River, which, although they are within a score of miles of the coast, follow it for nearly 60 miles before reaching the ocean. Eel River is the most important stream of the group, and to the east lie Mad River and Redwood Creek. Upon the headwaters of the former, Eel River has been encroaching and has already made important captures. The whole of the region bordering the Klamath Mountains on the southwest may be most conveniently referred to as the northern end of the Coast Range. The same peculiar drainage direction (NW.-SE.) may be seen in the head of Thomas and Grindstone creeks, which flow into the Sacramento and mark the Yallo Bally peaks as the southern terminus of the Klamath Mountains near the fortieth parallel. The Cascade Range of Oregon and northern California is built up largely of igneous products along a line of great volcanoes, the last of which to the southward is Lassen Peak, occupying a depression at the northeast corner of the Sacramento Valley between the Sierra Nevada and the Klamath Mountains, whose outlines are indicated on the accompanying map (Pl. I)[1].

The Klamath Mountains embrace a large number of ridges and peaks having special names. The most important of these are the Siskiyou (Preston Peak, 9,000+ feet), Salmon (Thompson Peak, 9,345 feet), Scott (Mount Eddy, 9,151 feet), Bully Choop (7,073 feet), and Yallo Bally (8,604 feet) along the crest of the range. They are all more or less conspicuous peaks rising above the general plateau of the group.

[1] There being some confusion in the use of names of mountains southwest of Mount Shasta, letters of inquiry concerning common usage were addressed to the thirty-six postmasters of the region, and the names Salmon, Scott, and Trinity are placed on the map in accordance with the majority of the replies. Concerning the Trinity Mountains the opinion was unanimous.



SECTIONS ILLUSTRATING STAGES IN THE NORTHERN COAST RANGE REGION SINCE EOCENE TIME.

A, Klamath stage; *B*, Bellspring stage; *C*, Sherwood stage; *D*, generalized section of coast and river valley, illustrating the records of the various stages from the Garberville to the marine-terrace stage, inclusive.

The numbers indicate the features developed during the stages described on pp. 11–14.

BRIEF SUMMARY OF EVENTS.

The topographic development of the Klamath Mountains involved a long and complicated series of changes, which it is the purpose of this paper to set forth. To facilitate the presentation and discussion of the facts it seems desirable to give first a brief historical outline, enumerating the events in their sequence and designating the more important of the special features as they develop.

Some of the general topographic features of the Klamath Mountains had their beginnings at least as far back as the early Mesozoic, but it is not the writer's purpose to go into the past beyond the close of the Eocene, from which time to the present the sequence of events appears to have been as follows:

1. *Klamath stage.*—The Eocene closed in the Klamath Mountain region with an uplift initiating a long cycle of erosion, which reduced the Miocene land surface to very gentle relief, practically to a peneplain, the Klamath peneplain. (See Pl. II, *A*.)

While the Klamath peneplain was developing, approximately the whole of the adjacent northern end of the Coast Range region of California southwest of the drainage of Trinity River and its tributaries was covered by the sea (see shore line at close of Klamath peneplain stage, Pl. I) and received a correlative deposit of Miocene sediments.

2. *Post-Klamath faulting.*—Toward the close of the Miocene the sediments which had been laid down during the Klamath stage were displaced and tilted by a series of faults, and raised a little above sea level. The adjacent portion of the Klamath Mountain region, embracing the Klamath peneplain already developed, was at that time but little disturbed either by the faulting or by the uplifting, so that the Klamath peneplain, although slightly broken, remained evident.

3. *Bellspring stage.*—After the close of the disturbance just noted the land remained still for a considerable time, allowing the low hills of soft Miocene beds along the coast to be reduced nearly to sea level, thus developing by subaërial processes a peneplain over the region of the northern end of the Coast Range. This peneplain is practically continuous with the peneplain of the adjacent Klamath Mountain district. To distinguish it from the Klamath peneplain it may be designated the Bellspring peneplain, after a locality where this feature is well preserved. (See Pl. II, *B*.)

4. *Post-Bellspring uplift.*—With the completion of the Bellspring peneplain in its extension over the northern portion of the Coast Range, there came an uplift which affected the whole coast of northern California and Oregon. The uplift was differential, being about 500 feet along the coast and an increasingly greater amount toward the crest of the Klamath Mountains.

5. *Sherwood stage.*—The uplift just noted was succeeded by a long halt, during which the land stood still and allowed the cycle of ero-

sion to advance to the development of a peneplain over wide stretches of soft rocks locally along the coast. This peneplain has its greatest extent about the South Fork of Eel River and Sherwood, and may be called the Sherwood peneplain, to distinguish it from the Bellspring peneplain, which lies 500 feet higher. (See Pl. II, *C*.)

Along the Oregon coast, where the more ancient and durable rocks of the Klamath Mountains form much of the shore, the development of the Sherwood peneplain was not marked, but from the Chetco River south, where softer beds of Miocene age form much of the land, the Sherwood peneplain attained a wide area.

Extending inland from the level of the Sherwood peneplain along Rogue River and the Klamath and Eel rivers are broad valleys of Sherwood stage high above the present beds of these streams, and wherever soft beds occur, as at Round Valley, the valley of Sherwood stage widens to a local Sherwood peneplain.

6. *Post-Sherwood uplift.*—At the close of the Sherwood stage the whole region of the Klamath Mountains and adjacent Coast Range experienced a differential uplift. Along the coast the uplift was about 500 feet. The amount increased toward the crest of the Klamath Mountains and greatly invigorated the streams, initiating a new cycle of erosion.

7. *Garberville stage.*—At the close of the uplift just noted began the Garberville stage (illustrated, with succeeding stages, in Pl. II, *D*). The Bellspring peneplain nearest the coast then stood at an elevation of 1,000 feet, and the Sherwood peneplain at 500 feet. The Garberville stage was not so long as the Sherwood, and yet it was long enough to permit the rivers where the rocks were relatively soft to carve out broad valleys of gentle slope in the yet earlier valleys of the Sherwood stage. The two series of valleys, of the Sherwood and Garberville stages, are rarely sharply distinguishable. Perhaps the valley best illustrating the Garberville stage is that of the South Fork of Eel River, where it cuts across the Sherwood peneplain in the vicinity of Garberville.[1] The valleys of both stages were broad and often in marked contrast with the narrow valleys of later date.

8. *Post-Garberville subsidence.*—The Garberville stage was brought to a close by a subsidence, the depth of which, although small, increased to the eastward, not only ponding the streams but admitting the tide in the southern branches of the Trinity as far as Hay Fork, within a few miles of the present crest of the Klamath Mountains.

9. *Hay Fork stage.*—In the water bodies thus formed fluvio-estuarine sediments were deposited during the Hay Fork stage, filling the old valleys. Among the sediments of this stage shales have been found containing sharks' teeth and Miocene leaves. Volcanic dust and pumice play an important rôle in this old valley filling, and traces of coal are of common occurrence.

[1] The town of Garberville is on the river in a narrow valley far below the earlier valley of the Garberville stage.

EVEN CREST OF COAST RANGE, KLAMATH PENEPLAIN, AS SEEN FROM ROSEBURG, OREG.

10. Post-Hay Fork uplift.—Succeeding the Hay Fork stage came an uplift affecting the whole coast. In northern California the uplift was in the neighborhood of 1,500 feet, raising the land at least 600 feet above the present level, and forcing the coast westward to the border of the continent adjoining the deep sea. During this upward movement there was considerable displacement, for the fine sediments of the Hay Fork stage are in places somewhat tilted.

11. Continental border stage.—High altitude and rapid erosion prevailed during the continental border stage. The revived rivers swept away much of the unconsolidated material which had filled the old valleys and cut canyons generally in them, but in some cases the streams were wholly diverted from the old channels and cut new ones. Much of the Miocene deposits along the coast was removed during this stage, and valleys were cut across the continental border, which is now submarine, to the sea beyond.[1] The date of this erosion is indicated as occurring between the Miocene (Empire epoch) and late Pliocene (Battery Point epoch) by an unconformity at Battery Point near Crescent City. The intensity of the erosion during the continental border stage must have been greatest near the sea. Its most pronounced effects on the continental border, now submarine, must be largely obscured by later deposits along the coast.

12. Post-continental border subsidence.—A subsidence of probably 700 feet submerged the continental border and carried the land somewhat below its present level, where it remained stationary for a while.

13. Battery Point stage.—The fossiliferous Pliocene San Diego beds of Battery Point, near Crescent City, were deposited during this stage in shallow water unconformably upon a post-Miocene surface of erosion. The stage was probably a short one and was brought to a close by further subsidence.

14. Post-Battery Point subsidence.—After the deposition of the Battery Point beds, perhaps with some oscillation, a general downward movement of about 1,500 feet ensued all along the coast of northern California and southern Oregon, submerging the coast to approximately the level of the Sherwood peneplain. This submergence must have had a profound effect upon the land drainage, and filled many of the narrow valleys to great depths; but although the exact extent of the subsidence is not known, as the coast was mountainous, the sea did not advance far inland before the end was reached and the return swing began, which is recorded in the elevated beaches of the following stage.

15. Marine-terrace uplift stage.—The marine-terrace stage opened apparently with the Sherwood peneplain near sea level, and from that position the land has risen to its present altitude, not by one

[1] Two papers recently published, one by W. S. Tangier Smith in Science, the other by O. H. Hershey in the Journal of Geology, should be referred to in this paper, but they are not available while proof is in hand, in the field, and can only be mentioned in this place.

single uplift, but by a number, separated by halts which were in some cases sufficiently long to allow the waves to develop prominent beaches, with sea cliffs and marine terraces, all of which are capped more or less completely by Pleistocene marine sediments. The first or oldest of this series of marine terraces must now be highest on the slope up from the sea, while the newer ones range successively downward to the present beach. The terraces are numerous and occur at many levels. The highest one yet found is 1,500 feet above sea level, and marks approximately the point at which subsidence changed to uplift. The two most prominent terraces are about 100 and 1,000 feet above sea level.

While the waves were cutting terraces on the coast the rivers were cleaning out their filled valleys, or perhaps in some cases cutting new canyons around the filling.

16. Coos Bay subsidence.—The latest movement on the coast of Oregon from Bandon northward has been one of slight subsidence, permitting the tide to run up the rivers many miles.

The sequence of events may in a general way be illustrated by the diagram, fig. 1, in which the horizontal component represents time and the vertical component represents altitude of the land—the Klamath peneplain in particular—with reference to sea level.

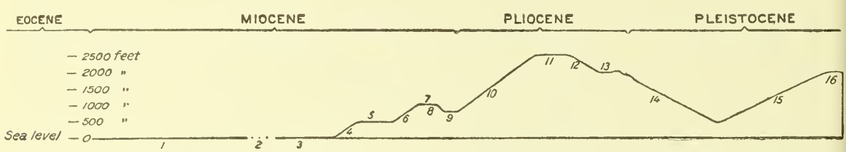


FIG. 1.—Diagram illustrating the movements of the Klamath peneplain with reference to sea level.

Notwithstanding the post-Klamath faulting (2) the land remained for a long time (1–3) at approximately the same level, allowing the development of the Klamath and Bellspring peneplains. The uplift (4), followed by a halt (5), resulted in the Sherwood peneplain. Another uplift (6) and halt (7) led to the features of the Garberville stage. The long upward movement (1–7) was followed by a slight recoil (8) and halt (9), filling the estuarine valleys, before the great uplift (10) which forced the sea back to the continental border. A time of high altitudes (11) ensued. The end of the swing was reached and subsidence (12) set in, halting (13) for a short interval before the greater downward movement (14) which depressed the Klamath peneplain to within about 500 feet of sea level. Elevation (15) began again; it was marked by many halts, when marine terraces were carved; and finally there has been a local sag (16) along the northern coast of Oregon.

Owing to the lack of characteristic fossils at important points the reference to the geological time scale in fig. 1 is not fully satisfactory.

KLAMATH PENEPLAIN ON IRON MOUNTAIN, SEEN FROM SOUTHERN END OF BARKLOW MOUNTAIN, CURRY COUNTY, OREG.

If the Wymer beds on the border of the Klamath peneplain should turn out to be Pliocene and those of the Hay Fork stage later than the Miocene, the Miocene would be largely excluded from the sequence.

THE KLAMATH PENEPLAIN.

The Klamath Mountains are characterized in many places by flattish or gently rounded summits and an approximate accordance in the altitudes of even-crested ridges, giving to these highlands the aspect of a dissected plateau. The upper portions of the principal divides, after attaining a considerable altitude above the sea, have in places broad tops on which the relief features are terraces or low, rolling hills. Sharp peaks above this level of gentle relief are found, with rare exceptions, only among the highest parts of the range. The original more or less irregular plateau surface, of which we now have only remnants, for convenience of reference may be for the present assumed to be due to a form of planation, and designated the Klamath peneplain, although its approach to a plain is in places not clearly marked, because (1) the original prominences were not completely reduced to the general level, and because (2) it has been so warped and broken by differential change of level as to partially obscure its original character.

REMNANTS OF THE KLAMATH PENEPLAIN.

In the northern part the Klamath peneplain is well marked in the densely forested summit of the Coast Range. Seen from the vicinity of Roseburg, Oreg., the range presents an even crest (Pl. III) rising to an altitude of from 2,500 to 3,000 feet. From the summit of this bold escarpment, which faces the east, the crest is seen to be the edge of a broad plateau whose smooth or gently rolling surface is deeply trenched by streams. In the cross canyon of the range its synclinal structure of Eocene sediments is well displayed and the flattish summit is clearly a plain of erosion. Extensive general views of this portion of the plateau are difficult to obtain on account of the gentle relief of its general surface and the heavy forest covering. One of the best views of the east front may be had from Tyee Mountain, which has an altitude of 2,655 feet. The plateau has a gentle inclination westward. Its western edge, although rising nearly 2,000 feet above the sea, is much less distinct than its eastern. To the southwest the Klamath peneplain rises gradually nearly to the limit of the Eocene sandstone in Eden Ridge and Blue Knob, on Rogue River, where it has an altitude of 3,787 feet. The crest of this portion of the range may be seen from Barklow Mountain, at the head of the South Fork of Sixes River. The uniform character of the arenaceous sediments gives the peneplain considerable uniformity. Going south near the coast, before reaching Rogue River, one finds the older and

harder rocks appearing in great variety and giving rise to much greater variation in topographic features. On the hard saxonite of Iron Mountain, 20 miles southeast of Port Orford, the peneplain rises in a low, broad ridge to 4,000 feet (Pl. IV), possibly the highest point of the range in Oregon north of Rogue River. The peneplain gradually declines toward the coast, where the now highest peaks, Butler (2,923 feet) and Avery (2,613 feet), stand out as hills a few hundred feet above the Klamath peneplain.

Between Sixes River and Floras Creek the rolling plateau surface is well preserved in Edson Butte (2,781 feet), declining gently westward to Eightmile Prairie, at an elevation of 2,363 feet.

A flat-topped mountain between Blackberry and Panther creeks preserves the plain near Elk River at about 2,500 feet, and just north of Rogue River an undulating plain forms the crest of the divide in the Prairie Mountains east of Lobster Creek, with an altitude rising eastward from 2,200 to 3,000 feet.

South of Rogue River the drainage is more regular to the California line, and the divide between Illinois River and the coast, seen from Sunset Peak, preserves the Klamath plain in many ridges and spurs.

A short distance south of Pistol River the plateau front advances nearly to the coast and the descent to the shore is steep. For this reason the stage road gradually ascends over the terraced border to the summit of the plateau near Irma, at an elevation of nearly 2,000 feet. From the bald hills by the road a good view of the plateau remnants to the southeast may be seen. The broad dome of Bosley Butte, a few miles from the plateau front, is prominent, and rises considerably above the general level of the Klamath peneplain.

From Chetco Ferry, near the coast, Mount Emery is distant about 9 miles, and is easily reached on horseback. It rises about 500 feet above the general level, and from its southwestern slope affords one of the finest general views of a peneplain to be found along the coast. The display of even-crested ridges, beyond which rise the irregular summits of the Siskiyou Mountains, is impressive. The peneplain has an inclination westward of $1\frac{1}{2}°$, reaching the sea front just south of Chetco River at an elevation of 1,700 feet. Mount Emery is composed largely of andesitic rocks and has a flat summit whose elevation is nearly 3,000 feet. To the northeast and east are summits of greater elevation, but they appear less regular along the crest line. Their color has determined their name, Red Mountains, and suggests that they are within the great area of peridotite traversed by Illinois River and the head of Pistol River. Farther northeast is a large, flattish tract, rising to an altitude of 4,400 feet, with crests near by reaching 5,000 feet. The peneplain represented by the summit of Mount Emery and the flat tracts to the northeast is less regular than the one 500 feet below, seen from the slope of Mount Emery. Whether there are really two peneplains about Mount Emery, or only one which has been

A. KLAMATH PENEPLAIN, 17 MILES WEST OF WALDO, ON McGREW ROAD (ABANDONED).

Looking southwest across Middle Fork of Smith River. Elevation 4,000 feet.

B. KLAMATH PENEPLAIN ON DIVIDE BETWEEN COLUSA AND LAKE COUNTIES, CAL., SEEN FROM NEAR VERNADO.

faulted, could not be fully determined during the writer's brief stay in that region.

The next ascent to the Klamath peneplain was by the old Wymer wagon road, about 7 miles north of Peacock's ford of Smith River. At this point the marine deposits laid down upon the seashore when the peneplain had reached its greatest development are well preserved and locally full of fossils, both marine shells and leaves from the adjacent land. The peneplain rises gradually eastward from 2,450 to 4,000 feet, and was early recognized as affording the easiest course, although longest and stoniest, for the construction of a wagon road from Crescent City to Illinois River and Grants Pass. The Wymer and McGrew roads are both on this plain. The McGrew road crosses the plain west of Waldo at a little over 4,000 feet, and affords a fine view of the plain as it approaches the Siskiyou Mountains, which rise above it in a group of irregular and prominent peaks, among which Preston Peak (altitude 9,000+ feet) is the most conspicuous. To the southwest the crest of the ridge forming the divide south of the Middle Fork of Smith River (Pl. V, *A*) shows the plain dipping westward from the Siskiyous, reaching the coast a few miles south of Crescent City, where, at an elevation of about 1,300 feet, a fringe of the Sherwood peneplain appears and the descent to the seashore is so abrupt that the stage road is forced to climb to the summit of the plateau.

South of Klamath River another ascent to the plateau was made in crossing from Mad River at Korbel to Hoopa Valley on the South Fork of Trinity River. The divide between Mad River and Redwood Creek is in the Coast Range, and its flat crest is part of the Bellspring peneplain. It rises in flat-topped Bald Mountain by Acorn to 3,000 feet, and affords an extensive view of the country. The next divide to the east beyond Redwood Creek belongs to the Klamath Mountains. On the wagon road from Berrys to Willow Creek this divide has an elevation of nearly 3,600 feet, and at 2,500 feet on the eastern side affords an excellent view in the direction of the light-colored granitic peaks about the head of Salmon River. They stand out as distinct prominences upon the Klamath plain, which rises in that direction to over 6,000 feet.

With Oscar H. Hershey an ascent was made to the summit of Mount Courtney, one of the Salmon Mountains a short distance southeast of Thompson Peak. It stands near the head of the South Fork of Salmon River and rises to an altitude of over 9,000 feet. From this prominent viewpoint the general agreement in altitude of the principal ridges is impressive, and although the examination was not sufficient to determine satisfactorily the relations of this plain of low relief to the Klamath peneplain, the evidence suggests that they are of the same age.

As one proceeds southward from Eureka the heights of Bear and Mail ridges afford extensive views eastward, disclosing the long, even crest of South Fork Mountain, which constitutes the divide between Mad River and the South Fork of the Trinity. That remarkable crest of ancient schists is one of the best-developed portions of the Klamath peneplain, and was crossed at two points in 1889,[1] at an elevation of nearly 6,000 feet. Its composition and general features as part of the great plain of erosion were then noted.

To obtain a closer view of the South Fork Mountain country an ascent was made from Blocksburg to Lassic Peak (5,875 feet), whose platform, at an elevation of 5,600 feet, is evidently in an ancient plain of very gentle relief. The peak being but little above the general level of the plain, the view of that feature is remarkably impressive, and it is evident that if the canyons were filled up by returning the material carried away by the streams, thus restoring the original condition, the surface would be approximately a plain. The even crest of South Fork Mountain is broken near the middle by a low, rounded knob known as Picket Peak, beyond which the crest rises toward the Yallo Bally Mountains, where traces of the plain reach 7,000 feet.

THE BELLSPRING PENEPLAIN.

The Mad River divides for long stretches are more regular in their crest lines than those of the country to the southwest traversed by Eel River and the Mattole, although there are traces of plains and a striking correspondence in elevation in many places throughout the whole region.

The greater regularity of the peneplain on the Mad River divides as compared with the peneplain of the region to the southwest, is related to the Miocene shore line at the time the Klamath peneplain attained its greatest development. The position of the Miocene shore line is indicated, approximately, on Pl. I, and near it the Klamath peneplain would be expected to show a more advanced degree of degradation than farther inland.

The northern end of the Coast Range was beneath the sea during the Klamath peneplain stage, and was brought to the surface by the faulting and tilting of the Miocene sediments bordering the Klamath peneplain.

The consequent degradation in course of time reduced the north Coast Range region to a peneplain—the Bellspring peneplain, which is practically continuous with the Klamath peneplain—but the hard rocks were not so completely reduced as in the adjacent portion of the Klamath Mountains, where, without essential change of base-level during the tilting of the Miocene, the peneplanation continued through both

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 408.

ALDER SPRINGS.

Looking north across Grindstone Creek, Glenn County, Cal. Elevation 4,269 feet. Photograph by Burt Cole, 1900.

stages. Although it is possible to distinguish the Klamath and Bellspring peneplains in places, it is not possible everywhere, especially about the southern end of the Klamath Mountains and along the border of the Sacramento Valley, where all remnants will be considered together in connection with the Bellspring peneplain.

REMNANTS OF THE BELLSPRING PENEPLAIN.

Bear Ridge has considerable flat tracts at elevations between 2,000 and 2,500 feet, although Mount Pierce, which is itself flat topped, rises to 3,278 feet. In Rainbow Ridge the gentle features bulge up to 3,400 feet, but in Kings Peak, farther south toward Shelter Cove, the prominences rise to a little over 4,000 feet and thence gradually descend with an even crest line overlooking the coast to a lower and extensive plain drained by the South Fork of Eel River.

To the southeast Mail Ridge rises and appears to become irregular, but when one ascends on the stage road to Bellspring, approximately 4,000 feet, the upland surface is seen to be of gentle relief, although it is less regular than that of the divides about Mad River. Near the northern end of Red Mountain is a prominent, unsymmetrical hill, with long, gentle, easterly slope and steep in the opposite direction, suggesting faulting; but it is possible also that the form is determined by the position of the strata. However this may be, it is clear that the gentle-featured surface has been much broken and warped.

Laytonville lies in a long valley at the eastern base of Cahto Peak, whose flattish summit of sandstones rises to an elevation of 4,251 feet, affording an excellent general view of that portion of the Coast Range. Here may be seen to advantage not only the somewhat irregular, although, on the whole, gentle features of the upland surface (Bellspring peneplain), but also the lower plain (Sherwood peneplain) in the valley of the South Fork of Eel River. The lower plain, some distance away, lies about 1,400 feet below the gentle upland of Cahto Peak, and sweeps about the western and southern base of the mountain to form the divide between Eel River and the coast.

The high hills opposite Ukiah, forming the divide between Russian River and Clear Lake, when seen from Calpella, appear to have irregular crests largely covered with greasewood, but when seen from the southern side are much more regular in outline and comparable with Bartlett Mountain, which forms the even-crested divide between Clear Lake and Bartlett Springs. Bartlett Mountain dips SE. 2°, and to the northwest is succeeded by Little Horse, Big Horse, and other flat-topped mountains, clearly preserving large tracts of the Bellspring peneplain. Above the point crossed by the old road to Bartlett Springs the ridge has an altitude of 5,000 feet. The crest is comparatively smooth, covered with timber, and easily traveled. Good views from this plain show that it rises northwestward to the head of Eel River,

where, in the broad crest of the range, it joins the Klamath plain of the western slope. The even-crested divide between Cache Creek on the one hand and Stony and Bear creeks on the other carries the Bellspring peneplain eastward into the Sacramento Valley, while to the northwest, as seen from the summit of Bartlett Mountain, it rises to the flat, snow-covered (October 11, 1900) crest, Snow Mountain, at an elevation of about 7,000 feet, forming the line between Lake and Colusa counties. Pl. VI, reproduced from a photograph by Mr. Burt Cole, illustrates the general flatness of the summit region (Klamath peneplain) as seen from a distance at a somewhat lower level. To the left of this view, beyond the crest of the range, is "Ocean View," at an elevation of 6,700 feet, from which the outlook to the south is given in Pl. VII. Snow Mountain (summit, 7,040 feet) and Mount St. John rise a little above the flat portion of the Klamath peneplain.

Beyond Bartlett Springs, 20 miles toward Williams, the stage road crosses the Bear Creek divide. A short distance north of the stage station, at an elevation of 2,700 feet, it affords an extensive view of the peneplain rising northwest to the crest of the range, and to the east, northeast, and north the even-crested ridges of the Coast Range foothills stretch away for miles, forming the divide between Bear Creek and Stony Creek on the west and the broad alluvial plain of the Sacramento on the east.

The first crest crossed east of Leesville among the Bear Creek hills is 2,250 feet in altitude, and beyond Antelope Valley the front ridge, a few miles southeast of Vernado, overlooking the great plain of the Sacramento, has an altitude of 2,000 feet. To the southwest from the front ridge the view across these Bear Creek hills and a series of even-crested divides shows a remarkable development of the Bellspring peneplain (Pl. V, *B*).

Bally Mountain, a few miles southeast of the stage station, on the divide between Cache and Bear creeks, is a mass rising prominently above the peneplain about its base, and in places on the mountain slopes, as seen from a distance northeast, there appear to be traces of planation above the general peneplain, but the ascent of Bally Mountain could not be made in order to study the matter.

The Bellspring peneplain ends abruptly on the crest of the foothills along the western border of the Sacramento Valley plain in Colusa County. The bold front facing east has an altitude of nearly 2,000 feet, and extends southward more or less continuously through Yolo County into Solano County. South of the deep gap cut in this front ridge by Putos Creek the crest rises from 2,500 to 2,900 feet.

To the northward from Colusa County this front extends with decreasing height into Glenn County, and the Bellspring peneplain is finally brought down to the level of the later plain of the Sacramento Valley. Although the plateau front sinks northward, the plateau surface for some distance west of the front rises in that direction

KLAMATH PENEPLAIN SEEN FROM OCEAN VIEW (6,700 FEET), LOOKING SOUTH.

The peak in the far center is St Johns Mountain, Glenn County, Cal Photograph by Burt Cole, 1900.

and attains its greatest height about the head of Stony Creek. Where crossed by the road from Leesville to Williams the greatest altitude observed among the flat-topped hills was 2,110 feet, but on the road from Sites northwest to Stony Ford the Grapevine grade reaches a height of 2,700 feet and the crest rises to nearly 3,000 feet. A line running a little west of north through Bear Valley and the valley of Stony Creek separates the foothills of Colusa County from the mountains proper. West of this line are large areas of serpentine, but the foothills lying eastward are composed wholly, or almost wholly, of Cretaceous strata, usually dipping eastward at a high angle. Conglomerates, sandstones, and shales were cut at equal altitudes by the same plain, but now the sandstones and conglomerates appear in the even crests of the ridges, while the shales are in the intervening valleys, of which Antelope, Bear Creek, and Stony Creek valleys are the best examples. The even-crested foothills of Colusa County extend through Glenn County to Paskenta, where Paskenta Butte, or the lower flat summits near the road at the divide a few miles south of Paskenta, afford an excellent and impressive view of the plain marked by their summits. The peneplain, so well marked in the foothills, is greatly deformed along the eastern slope of the mountain north of the head of Stony Creek. About the head of Stony Creek and Bear Creek, in Colusa County, the peneplain which caps the foothills is continuous with that of the mountain crest about the head of Eel River. The peneplain rises westward to the crest of the range with a gradual change of slope from 1° to 12°, and then gradually flattens out again near the summit. Along Stony Creek the continuity has been broken by the broad valley, but from Elk Creek Hill, near the town of the same name, to one looking southward the former continuity of the plain across the valley is shown by the crests of the ridges, and their lower altitude suggests that there is a sag in the Bellspring peneplain along Stony Creek and that Stony Creek is a consequent stream.

In the divide south of Paskenta, as seen from Millsaps, the continuity is still nearly preserved. The peneplain of the foothills gradually increases its inclination from 1° to 3° or more as it approaches the mountain, until, without abrupt transition, it attains an inclination of 14°, passing into the oldest portion of the mountain slope and rising to the crest of the range. On the divide near the road on the east side, 2 miles south of Paskenta, the flat-topped hills are covered with well-rounded gravel, at an elevation of 1,450 feet, and afford a fine general view. The peneplain north of Thomas Creek is less broken, and the transition from the gentle slope cut upon the nearly vertical Cretaceous shales, sandstones, and conglomerates to the mountain slope of 10° and more is gradual and continuous, tending to confirm the view that the peneplain of western Tehama County is of the same age as that so extensively developed on the western slope

of the Klamath Mountains. To the southward the view of the Glenn County foothills presents a very smooth, even sky line, gently dipping eastward for miles. No one could see this slope and doubt the former continuity of the plain marked by the even-crested ridges in the foothills of Colusa County.

The eastern slope of the Klamath Mountains is less regular north of the fortieth parallel than farther south. The plain is warped and broken by displacement and erosion, but near the summit of the range the gentler features reappear in the platform of the Yallo Bally Mountains, which has a general altitude of about 7,000 feet.

The only point near the coast in California where the two plains have been separated is at the northern end of Bear Ridge, which is surmounted by an older plain of gentle relief at an altitude of about 2,500 feet, while on the north slope at 2,000 feet there is a well-marked plain cut upon the upturned edges of the Wildcat series. In Oregon north of Rogue River, although traces of the second plain have been recognized, they appear near the level of the Klamath plain and are scarcely distinguishable. It is possible, perhaps probable, that in some cases the lower plain is the same as the upper, the discordance in the elevations being due to faulting.

On the eastern side of the range is a peneplain below the Klamath peneplain, occupying about the same relative position as the Sherwood plain on the west slope. This plain stretches westward from the Bald Hills of Shasta County and its occurrence has been already described and illustrated.[1]

THE SHERWOOD PENEPLAIN.

In the foregoing part of this paper the plateau-making peneplains have been regarded as the Klamath and the Bellspring, although lower peneplains were mentioned as occurring at a number of places. The lower plain is most extensively developed along the South Fork of Eel River and about Sherwood, near the center of Mendocino County, at an elevation ranging from 2,400 to 2,800 feet on the divide between the head of the South Fork and Eel River and the main stream to the east. In Cahto Peak, about 20 miles northwest of Sherwood, the older peneplain is preserved at about 4,200 feet—that is, at least 1,400 feet above the Sherwood plain. The general views of the Sherwood plain were not so clear and extensive as was desired, but it appears to stretch far eastward and northeastward toward the crest of the range, possibly connecting with the one which occurs in Hay Fork Gap at 5,000 feet. It is much lower than the southeastern end of South Fork Mountain, which carries upon its even crest the Klamath peneplain at an altitude of over 6,000 feet. There thus seems to be an increasing difference in the altitude of the two plains toward the crest of the range.

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[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, pp. 406, 410, 412.

A. SHERWOOD PENEPLAIN, RISING WESTWARD FROM BALD HILLS, SHASTA COUNTY, CAL.

B. SHERWOOD PENEPLAIN OF BALD HILLS, SHASTA COUNTY, AND KLAMATH PENEPLAIN OF YALLO BALLY MOUNTAINS, TEHAMA COUNTY, CAL.

Its relation to the peneplain so well developed on the foothills of southern Tehama, Glenn, and Colusa counties, has not been determined.

From the Bald Hills of Shasta County the peneplain rises gradually westward (Pl. VIII, *A*) to the flattish crest of the divide, where the stage road from Red Bluff to Hay Fork crosses. The best view of this plain is obtained from the Bully Choop mine road, at an elevation of about 2,500 feet. As one ascends this road two peneplains appear to be visible, and their relation is shown in Pl. VIII, *B*, a view taken near Watsons Gulch, at an elevation of about 1,100 feet, looking S. 30° W. The lower plain capping the Bald Hills is the one which crosses the range in Hay Fork Gap at an elevation of nearly 5,000 feet and appears to connect the head of the South Fork of Trinity River and of Mad River in Trinity County with the Eel River country in the northern part of Mendocino County.

The higher plain seen upon the distant Yallo Bally Mountains in Pl. VIII, *B*, appears somewhat irregular, but from a level of over 4,000 feet its plateau character is marked. The upper plain is the Klamath peneplain and accords with that so well marked on the western slope of the Klamath Mountains. About the southern end of

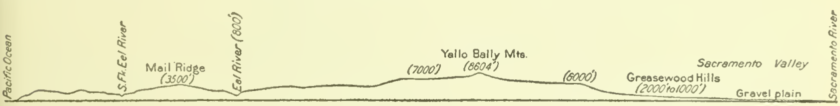


FIG. 2.—Generalized profile of Coast Range and Klamath Mountains on the fortieth parallel.

South Fork Mountain the two plains may again be observed, but it is by no means certain in places that the difference of level is not due to displacement and that both are not parts of the same plain. The matter can not be definitely settled until the topography and geology can be worked up in much greater detail.

In the vicinity of Klamath River there is an extensive deposit of gravel, forming the divide west of that stream from the South Fork of Trinity River to Gold Bluff on the coast, which belongs, approximately, to the Sherwood epoch, and which will be noted more particularly under the head of the earlier valleys of the Klamath River.

PROFILE ACROSS COAST RANGE AND KLAMATH MOUNTAINS NEAR THE FORTIETH PARALLEL.

Fig. 2 illustrates a generalized profile of a cross section of the Coast Range and Klamath Mountains near the fortieth parallel, which will give a clearer idea of the form of these uplands than may be gained from the fragmentary descriptions. No survey was made for this section, and the plateau feature is somewhat exaggerated by the omission of small valleys. When viewed from the lowlands along the coast or the stream canyon of the western slope, the country looks

decidedly mountainous, but when viewed from the crest of one of the high ridges the evenness of the summits becomes prominent and the range is seen to lack true mountain topography, except perhaps along the crest near the eastern edge, where the Yallo Bally, Bully Choop, Trinity, Scott, Salmon, and Siskiyou mountains stand out as peaks or clusters of peaks in the general plain.

At the western end of the profile, by the sea, is represented the 1,000-foot terrace, which, as we shall see later, is one of the most prominent and persistent along the coast. Above it the plateau front rises to an altitude of about 2,000 feet. The even crests of the ridge at this point are plainly visible from Mail Ridge near Harris, at an elevation of 3,500 feet. In the middle view is the Sherwood peneplain, but the broad valley of the Garberville stage is scarcely visible. The upper slopes of Eel River Valley are long and gentle, while the lower ones are short and steep. Beyond Eel River the country is less regular than farther south, where, as seen from the flat summit of Bellspring Hill, the Sherwood peneplain has considerable development and passes beyond the southern end of South Fork Mountain, which is capped by the Klamath peneplain. South Fork Mountain is too far north to appear in the above profile. About South Yallo Bally the Klamath peneplain is preserved and after passing the crest inclines gently eastward for about 6 miles, descending to 6,000 feet, and then the slope plunges rather steeply 4,000 feet toward the Sacramento Valley. At an elevation of about 2,000 feet the slope again becomes gentle, with more or less irregularity due to erosion. Still farther eastward a peneplain regarded as the equivalent of the Sherwood plain of the west slope soon becomes gravel covered, and so remains for the most part until it passes beneath the terraces and alluvial plain of the Sacramento River.

ELEVATED BEACHES ALONG SEAWARD BORDER OF KLAMATH PENEPLAIN.

THE COASTAL PLAIN.

The greater portion of the coast from Coos Bay, in Oregon, to the mouth of Eel River, in California, a distance of over 250 miles, is bold and rocky, rising in steep slopes from the shore line. The reason for this is found in the fact that the land is composed generally of hard rocks. There are three exceptions to this general rule, where stretches along the coast are bordered by a coastal plain generally less than 100 feet above sea level. These three tracts are, in part at least, connected with deposits of soft Neocene strata, to which is due the greater erosion. The first, beginning at the north, extends from Coos Bay to beyond Cape Blanco; the second is about the mouth of Smith River and Crescent City; and the third extends from Little River, near Trinidad, to Eel River about Humboldt Bay. These coastal plains

FIN ROCK AND CAPE BLANCO, OREGON.

are arable, and in some places densely forested, their tillage and lumbering industries furnishing occupation for the greater number of their inhabitants. The mountains bordering the plains on the east are in strong contrast to them and have a scanty population.

For the information of those who may be interested in these small coastal plains as physiographic types a fuller statement is made concerning some of their features.

The outer border is the crest of the sea cliff, which ranges from 50 to 225 feet in height, and is illustrated in Pl. IX. The cliff is composed chiefly of soft Miocene sandstone, overlain by later deposits of sand and gravel, and contains near its base, as shown in the illustration, a layer of marine shells. The soft sediments of the cliff are undermined by the waves of the beach and break away by their own weight, to be reduced to sand on the beach and spread by the undertow over the adjacent sea floor in new deposits. Where hard rocks or gravel occur on the sea cliff and wave action is vigorous, as about the head of Cape Blanco, the beach is more or less gravelly. By the attack of the waves the sea gradually advances upon the land and washes away in large measure the records of its earlier work.

The inner or landward border, which was formerly the shore line, is marked in places not only by a sea cliff, but by a mass of shore gravel. This feature is illustrated in Pl. X, *A*, where the gravel is mined for gold. On the right in the distance is the ancient sea cliff at the base of Maddens Butte, which has been connected with a gentler slope by its own talus. At its left is the coastal plain, underlain by deposits of gravel and sand derived from the cliff. When this coastal plain was formed the shore line was along the base of Maddens Butte, and the deposits now being mined were on the beach. The older hard rocks, such as form the butte and sea cliff beneath the surface soil, lie only a few feet beneath the gravel of the mine.

The surface of the coastal plain is generally even, but occasionally has ridges of wind-blown sand from the coast, to which they are closely limited. The plain from Bandon to Port Orford, although well covered with forest or a thick growth of shrubs, is for the most part sandy, with many small swamp patches. Here and there, from the accumulation of vegetable mold or fine sediment, the soil is fertile and cultivated. The same is true of much of the plain north of the Chetco River, but south of it are large stretches of fine farming land.

Some of the rocks are so hard as to have successfully resisted the attack of the waves when the coastal plain was formed and were not reduced to the level of the plains. They stand out as ledges on the plain. The most durable of the rocks encountered are of igneous origin, filling the chimneys of old volcanoes. Where such occur they stand out prominently as rock stacks upon the plain (Pl. X, *B*). These are exceptional. Throughout almost the whole of the coastal plain the rocks have been reduced below its level and covered by a thin coating of sand and gravel.

NORTH OF ROGUE RIVER IN OREGON.

The seaward edge of the Klamath peneplain is a very irregular line both in elevation and in its approach to the coast, and of equal or even greater irregularity are the ancient sea beaches on the slope from the edge of the peneplain to the coast.

A section of the marine terraces on the plateau front was made about 12 miles north of Port Orford, in the vicinity of Denmark, along the trail to White Mountain. It is illustrated in fig. 3. The coastal plain rises from a low border on the coast at Floras Lake to 98 feet at Denmark. It is part of the large plain, ranging in width from 1 to over 4 miles, generally having an altitude of less than 200 feet, and extending from near Coos Bay to Port Orford. Its surface is even and often swampy, and slightly rolling with sand hills. In Cape Blanco the plain rises at a sea cliff to 225 feet. Near the northern and southern ends the sea cliff of this coastal plain is over 100 feet in height, but from Bandon to Floras Creek it is lower, and is borbered here and there by barrier lakes or ponded streams. Continuing the section from Denmark, at 500 feet is a distinct terrace of

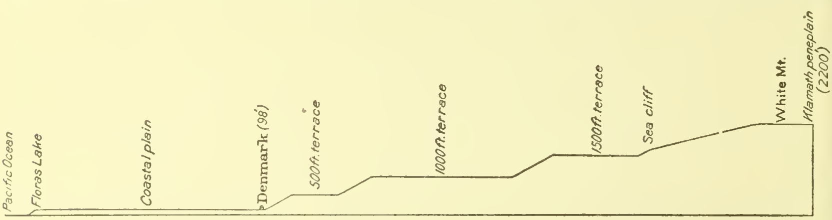


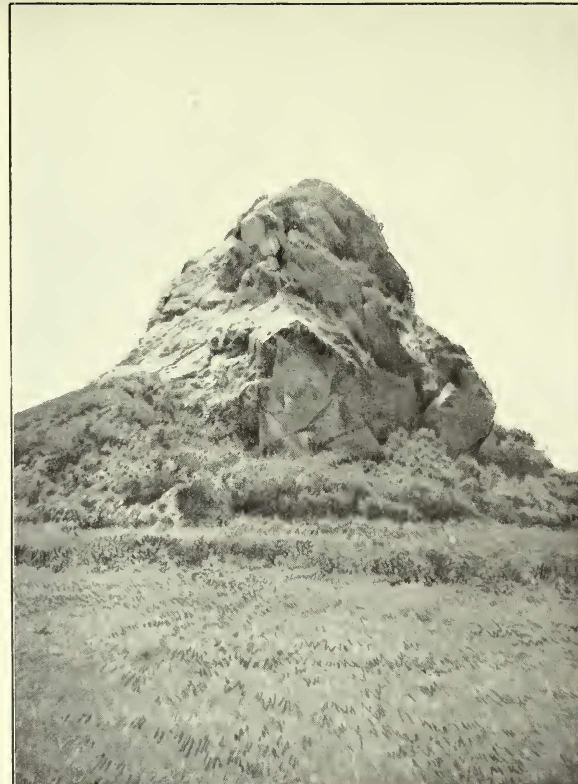
FIG. 3.—Profile of marine terraces 12 miles north of Port Orford, Oreg.

small extent, but at 1,000 feet is a much larger one, having a width of over a mile. This level is well marked on the next spur to the northward, 2 miles west of Hare, on the road from Langlois to Myrtle Point, and is cut on various hard rocks, such as serpentine, schists, and igneous rocks, as well as relatively soft sandstones. Some well-rounded pebbles are found at this place, marking the ancient sea beach. Marshy spots like those on the coastal plain also occur at this level.

Rising over a steeper slope to nearly 1,500 feet, one arrives at a third terrace, several miles in width. Like the 1,000-foot terrace, it has suffered much from erosion, yet its character is unmistakable. Eastward it is limited by a sea cliff. There is an abrupt change from the flat terrace to a steep slope, and then a more gradual change to the gentle slope of White Mountain summit, where the peneplain is traceable at an altitude of about 2,200 feet.

The sea beach at an elevation of 1,500 feet is the highest seen along the coast of the Klamath Mountains, and is very distinct at a number of points; for example, by the summit of Bills Peak in the south part of

A. MADDEN'S MINE, ON ELEVATED BEACH 5 MILES EAST OF CAPE BLANCO.



B. ROCK STACK ON COASTAL PLAIN 5 MILES SOUTH OF CHETCO RIVER, OREGON.

the Coos Bay quadrangle, as well as on the trail from Denmark to Eightmile Prairie and on the next divide beyond Crystal Creek. It occurs also on the divide between Edson Creek and Sixes River and at numerous other points farther south. The terrace connected with this beach is usually not wide, but on the whole is one of the best preserved of the upper terraces along this portion of the coast.

The 500-foot terrace is most extensively developed north of the Coquille, where it is separated from the coastal plain by several sea cliffs and intervening plains. The 1,000-foot terrace is well developed near the northern end of the Port Orford quadrangle, and is usually the most prominent of the elevated terraces on the coast.

At Port Orford the coastal plain ends and a prominent rocky sea cliff begins and continues with scarcely any interruption to the mouth of Euchre Creek, where a narrow belt of dune sands appears. Then comes a small coastal plain at an elevation of from 60 to 80 feet, extending from Ophir to the mouth of Rogue River. Near Ophir the cliff by the sea limiting the plain exposes Pleistocene sands to the sea level, but farther south it is cut on harder tilted sandstones and shales.

At Port Orford a prominent terrace at 300 feet spreads several miles to the northeast toward the Elk River divide. This divide rises by a number of terraces to the plains at the 1,000 and 1,500 foot levels. The latter is marked east of the stage road in the flat-topped hills about the head of Hubbard Creek. From the summit of Humbug Mountain the wide sweeps of the upper plain at about 1,500 feet is evident, and when that plain was at sea level Humbug Mountain and Colebrook Butte were small islands.

Just north of Rogue River higher terraces may be seen, but they are not so conspicuous as the coastal plain. The highest is best displayed along the trail up the southern end of Brushy Bald Mountain and is at an elevation of 1,500 feet. The terrace with its sea cliff is of but small extent and the rounded slopes above are distinct.

ROGUE RIVER TO CRESCENT CITY, CAL.

South of Rogue River a small coastal plain extends to Hunters Creek, to be replaced beyond by a more precipitous, irregular, rocky coast, which extends almost continuously for at least 20 miles to Lone Ranch Creek, 7 miles north of the mouth of Chetco River. Although this portion of the coast is bold, there are places where higher beaches attain considerable size. A section over the seaward slope was made from Scotts to the mouth of Lone Ranch Creek. The Klamath peneplain, fronting the coast, has an altitude of 1,800 feet. The first traces of terraces were seen at 1,500 feet, where the Lone Ranch road turns west to descend over the series of terraces to the coast. Although smaller terraces were seen at 1,140, 600, and 400 feet, the

principal terrace, having a broad plain at least a mile wide, ranges from 850 to 925 feet and corresponds closely to the 1,000-foot terrace seen elsewhere. The next largest terrace occurs at 250 feet and is well developed near Lone Ranch. This terrace is the coastal plain, and ranges in elevation from 250 feet at the northern end to almost sea level below Crescent City in California, a distance of 50 miles. There are small sea cliffs and minor terraces on this plain, but none of sufficient prominence to break the continuity of the plain, except along Smith River, where a broad flood plain with rich farms is a notable feature. The 1,000-foot terrace is well marked nearly to Chetco River, but south of that river the coastal plain lies at the foot of the plateau escarpment, as shown in Pl. XI, rising to an altitude of 1,700 feet. This plateau escarpment has a slope of $17\frac{1}{2}°$, and the absence of all clear traces of the terraces so well marked a few miles farther north suggests that it is a fault scarp. Only angular fragments were found along the east edge of the plain at the foot of this steep slope, where a beach would be expected if the plain developed after the faulting.

Crossing the Windchuck and entering California, one finds that the topography changes as Smith River is approached. The plateau front becomes less prominent and retreats to 5 miles from the coast, giving the coastal plain an extensive development as far south as Crescent City. This large coastal plain, less than 50 feet above tide, is due doubtless to the presence of soft Neocene rocks, remnants of which occur on the coast near Point St. George, as well as on the edge of the Klamath peneplain at an elevation of about 2,100 feet. An intermediate terrace was noted east of Crescent City at an elevation of about 700 feet, and two others of small extent north of Smith River at 1,350 and 1,450 feet, with small swampy patches like those of the coastal plain.

SOUTH OF CRESCENT CITY.

South of Crescent City 3 miles the coastal plain, which lies scarcely 10 feet above the sea level, runs out and the road mounts to the plateau formed apparently by the Sherwood peneplain at an altitude of about 1,300 feet. The seaward slope of the plateau front is 28° to 32° and shows no prominent traces of terracing below 1,000 feet. At that level, rising to the southeast, there is a densely wooded plain of considerable extent, connected by terraces, with higher levels farther eastward. Descending toward Wilson Creek the road here and there runs close to the steep slope overlooking the sea, and at a number of places crosses ravines of tributaries to Wilson Creek, which have been beheaded at an elevation of over 800 feet by the landward advance of the sea cliff. Whether this beheading is due to simple advance by marine erosion or to faulting along this bold slope is not certain, but most likely the latter, for if due to erosion alone there must be some cause, not readily seen, for such vigorous local action.

PLATEAU FRONT AND COASTAL PLAIN SOUTH OF CHETCO, CURRY COUNTY, OREG.

On approaching the mouth of Klamath River the high front of the plateau retreats from the coast, leaving a terrace of very even crest, 700 to 800 feet in height, extending to the sea cliff. From this level, on the road descending toward Wilson Creek, one sees a cove and valley, which he expects to be that of the Klamath River, and is disappointed and puzzled to find instead a lagoon and above it a broad, swampy valley leading over to Hunters Creek, and, a few miles farther on, to the Klamath River a short distance above its mouth. This broad valley is in line with the Klamath River above the mouth of Hunters Creek, and appears to have been the ancient valley of the Klamath, which then entered at what is now called False Klamath Cove.

South of the river the coast road skirts the edge of a platform which rises to 700 feet, but smoke and fog prevented a view sufficiently extended to determine whether the terrace is a part of the peneplain or is an ancient sea beach below the edge of that plain, the latter being much the more probable. The cutting off of the heads of the small streams which flowed from the coast toward the Klamath River, making in some cases notches 350 feet deep in the crest of the sea cliff, is convincing evidence of the advance of the sea upon the land. It is probable that the steep slope facing the sea is a fault scarp connecting with the faulting along the coast north of the mouth of the Klamath, with which it is parallel.

A flat-topped hill marks the 700-foot level by the road south of Redwood Creek, and affords a fine but limited view of this extensive slightly rolling plain. Beyond, the coast is bordered by a remarkable series of lagoons along the rather irregular edge of higher terraces. At Patricks Point a narrow coastal plain comes in again and continues, with some variation in width and altitude, to Mad River, where it is succeeded by the broad lowland of Humboldt Bay.

The plateau front marked by the Klamath peneplain at least 12 miles inland from this portion of the coast has an altitude of about 3,000 feet. The seaward slope of the low plain about Humboldt Bay is terraced, but being cut by many streams its continuity is interrupted and few terraces are prominent. On Lower Mad River the principal terraces rise from 200 to over 500 feet. Near the mouth of Eel River a terrace is marked at 600 to 700 feet; this terrace is succeeded farther inland by another at nearly a thousand feet, and this by a still higher one almost 2,000 feet above tide. The last two are developed on the north slope of Bear Ridge. From the mouth of Eel River to San Francisco the terraces of the abrupt coast have been described by Prof. A. C. Lawson,[1] who reports that the most pronounced and persistent terrace along the southern portion of the Humboldt County coast is that which appears very constantly between 900 and 1,000 feet.

If now we compare the terraces along the coast from the Umpqua

[1] Bull. Dept. Geol. Univ. California, Vol. I, p. 249.

to Humboldt Bay it appears that next to the coastal plain, ranging from 10 to about 200 feet above the sea, the 1,000-foot terrace is the most general, and that its occurrence at places all along the coast is evidence not only of a general long halt in the uplifting at that level, but also that the uplift since then has been approximately uniform. It is probable that much of the 1,000-foot terrace has been removed from its western edge by erosion.

MARINE DEPOSITS BORDERING KLAMATH PENEPLAIN.

AT CAPE BLANCO, OREGON.

Neocene deposits have long been known on the coast of Oregon and northern California,[1] but in only a few cases have they been described and their fossils studied. They are made of the sediments washed from the land in developing the Klamath peneplain, which they border, and their age is a matter of importance in determining that of the peneplain.

Along the coast of Oregon from the mouth of the Columbia to Yaquina Bay[2] these deposits are almost continuous. They are well exposed on the Columbia River near and opposite Astoria, along the beaches farther south, near the mouth of the Nehalem, at Tillamook Bay, and along the beach, bay, and river of Yaquina. Their next known occurrence is at Coos Bay, where the Empire beds, of Miocene age, are well exposed and have been carefully studied, both stratigraphically[3] and paleontologically. On this account they serve as a basis for comparison. South of the Coos Bay quadrangle, which extends to the forty-third parallel, Neocene strata occur between Floras Lake and Blacklock Point, and from Cape Blanco to the mouth of Elk River. Both of these localities are in the Port Orford quadrangle and will be more fully described in the folio.

On the north side of Blacklock Point there is a fine exposure of about 100 feet of soft, yellowish sandstone unconformably overlying gray sandstones of Cretaceous age. Near the base there are numerous fossils which Dr. Dall recognizes as Miocene of the Empire beds horizon.

At Cape Blanco, shown in the distance of Pl. IX, looking north, there is a sheer cliff of 200 feet of soft sandstones rich in fossils of the Empire beds. To the southward the Cape Blanco beds are exposed along the coast for 3 miles, dipping gently in the same direction to the mouth of Eel River, where they pass beneath the beach. They are full of fossils throughout, and large enough collections were made to leave no question as to their being Miocene of the Empire

[1] Bull. U. S. Geol. Survey No. 84, 1892, pp. 200-217, 223-227.

[2] Seventeenth Ann. Rept. U. S. Geol. Survey, Pt. I, 1896, p. 29.

[3] Coos Bay coal field: Nineteenth Ann. Rept. U. S. Geol. Survey, Part III, 1898, p. 319, and Pl. XLVIII. The formation is described also in the Coos Bay folio, No. 73. See also Dall's paper in Eighteenth Ann. Rept., Pt. II.

stage. The total thickness of the beds at Cape Blanco shown in fig. 4 is about 600 feet. In detail the section is as follows:

Section of beds at Cape Blanco.

Pleistocene (Elk River beds):	
Gravel	4–12
Shell bed, sands, and some gravel	7–75
(Unconformity.)	
Miocene, Empire beds (Cape Blanco beds):	
Argillaceous sands with some calcareous nodules	75
Conglomerate	25
Light-gray sand beds	50
Yellowish sandstone	30
Tuff	20
Yellowish sandstone	400
(Unconformity.)	
Cretaceous (?): Crushed gray sandstone.	

At the mouth of Elk River the Miocene shale occurs at the water's edge, and is overlain by nearly a hundred feet of Pleistocene gravel and sand (Elk River beds), near the base of which, close to the Miocene, is an unconsolidated shell bed rich in the great variety of its fossils. Near the mouth of Elk River the Pleistocene appears to rest

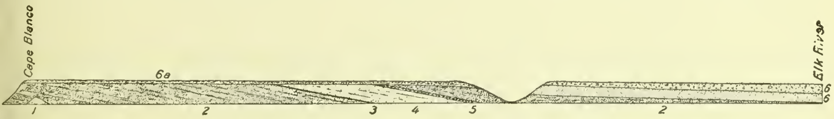


FIG. 4.—Section of beach bluff from Cape Blanco to mouth of Elk River, Curry County, Oreg. 1, Cretaceous sandstone; 2, yellowish sandstones and, near top, gray shaly sandstone; 3, tuff; 4, fine whitish sandstone, full of microorganisms; 5, conglomerate (2–5 Empire beds); 6, Pleistocene shell beds, sand, and gravel; 6*a*, point of view for Pl. IX.

conformably upon the Miocene, both rising gently toward Cape Blanco, where, as shown in fig. 4 and Pl. IX, the Pleistocene shell bed, rich in fossils, rests unconformably upon the Miocene.

Concerning the fossils collected from the Elk River beds, Dr. Dall remarks that they "are probably Pleistocene, all the species seeming recent, but they may be of the Merced horizon. A larger collection is needed to determine this point. They are not older than the newer Pliocene." There is considerable difference in the consistency of the Cape Blanco and Elk River beds. The former, although generally friable in the hand, are in many places hard, and most of the fossils occur in calcareous nodules and layers. In the Elk River beds, on the other hand, the sand, pebbles, and shells are not cemented. The unconformity between the Miocene and Pleistocene possibly represents a rather long interval, during which the Wildcat and perhaps the Merced series of California were deposited.

NEAR CRESCENT CITY, CAL.

From the mouth of Elk River southward along the coast no Miocene deposits were found for a distance of over 100 miles. They first appear at Point St. George, a few miles north of Crescent City

in California. From Point St. George both northward and southward for over a mile, soft yellowish and gray shaly sandstones and whitish shales full of fossils are exposed, and Dr. Dall refers these Point St. George beds, like those of Cape Blanco, to the horizon of the Empire beds. Although less than 100 feet of these strata are exposed, their determination is based on a rather large collection of fossils, and we may therefore speak with confidence of the Empire beds of Cape Blanco and Point St. George.

Somewhat similar beds occur by the wharf at Crescent City (Crescent City beds), and among their fossils Dr. Dall recognizes *Pecten parmeleei* and *Terebratalia hemphilli*, species heretofore known only from the southern California Pliocene.

It is probable that these soft Miocene and Pliocene beds have a wide extent under the Pleistocene of the low, broad coastal plain extending from Smith River to a point 3 miles south of Crescent City. However this may be, it is certain that they once extended 10 to 12 miles inland and have largely disappeared through erosion. Proof of this statement is found in the occurrence of Neocene deposits on the edge of the plateau at an elevation of about 2,200 feet along the old Wymer stage road, in section 20, about 13 miles northeast of Crescent City. North of the old Harvey place, where Thomas Haley now lives, a thin coating of the soft, iron-stained, slightly indurated shaly sands is exposed on the banks of the road for several miles, and has furnished numerous imperfect casts of mollusks as well as impressions of leaves. A short distance farther eastward, in an excavation made by Mr. Williamson near his barn, in section 22, a very fine, soft, gray, sandy clay, very slightly indurated, is rich in shells, many of which are microscopic. At the surface this bed weathers rusty, and the prominent shells are removed from the casts, so that the rock appears like the one on the road farther west.

The deposits of the two localities just mentioned will be called, for distinctness, the Wymer beds. They are very thin, resting on the surface of schists, peridotite, sandstone, and other rocks which have been cut down to an approximate plain. These fine argillaceous sediments are composed largely of kaolinic material, with much angular quartz of disintegration and numerous minute siliceous organisms of radiolarian types. When heated it blackens and then becomes lighter, like the bituminous shales of the Monterey series. The Wymer beds on the edge of the Klamath peneplain evidently record closely the time of most complete peneplanation. Concerning these fossils Dr. Dall remarks: "No. 5541 (from Wymer road), a friable yellow shale, with very imperfect casts of bivalves, and part of No. 5552 (from Williamson's barn), which is pale straw color but otherwise similar, have a Miocene aspect, but they are not of the Empire beds horizon." This remark was based on the presence of a Trochita, concerning which Dr. Dall remarks later: "On looking up the literature, I find Gabb

records finding a Trochita, which agrees very well with the casts in the soft yellow shale. It came from the Contra Costa Miocene of Walnut Creek. All the California Trochitas are Miocene, but an Eocene species occurs in Alaska. No living Pliocene species are known, though the allied *Galerus* occurs. Gabb says[1] that his shell was probably new, but he desired to await more material before naming it. It is probably of the San Pablo horizon."

The material from these localities is so fragile and the fossils are so poorly preserved, especially in the weathered portion, that their age must be considered doubtful until a palæontologist can study the fossils in the field and make out a fauna complete enough to give value to estimated percentages of living and extinct species. Near the eastern limit of the Neocene deposits found in Humboldt County about Bridgeville, and thus at least in a measure corresponding to those of the Wymer beds, are Miocene species. The beds of the Bridgeville region, except where lithified locally by carbonate of lime, are very soft, like the Wymer beds.

In the Wymer beds, near the fossil shells, were found a number of leaf impressions preserved in oxide of iron. These have been studied by Dr. F. H. Knowlton, who reports as follows:

> The material submitted is a loose, friable, highly ferruginous sandstone, not well fitted for retaining plant remains. The plants consist of leaves and fruits, but not a single example is preserved entire. From a somewhat hasty study of these fragments I am able to identify with reasonable satisfaction the following-named species: *Magnolia lanceolata* Lesq., *Persea pseudo-carolinensis* Lesq., *Laurus salicifolia?* Lesq., and *Quercus* sp.
>
> These species, fragmentary and unsatisfactory as they are, seem to indicate that the beds in which they occur are of the same age as the so-called auriferous gravels. *Magnolia lanceolata* was first found in the Chalk Bluffs of Nevada County, Cal., and I have recently obtained it from the Mascall beds of the John Day Valley, Oregon. *Persea pseudo-carolinensis* came first from Table Mountain, California, and has since been reported by Lesquereux from Corral Hollow, California, but of this latter determination I am uncertain. I am in doubt as to the leaf I have referred to *Laurus salicifolia*. Only a portion out of the middle of a leaf is present and the determination must be regarded as open to question. This species was originally described from Corral Hollow, California.
>
> From the evidence at hand it seems safe to say that the affinities of these beds are with the auriferous gravels, or Upper Miocene.

In order, if possible, to determine more closely the age of the Neocene beds of the coast of northern California, Dr. Dall spent a part of the summer of 1901 in that region, and concerning the Williamson Barn locality he reports by letter of October 28, 1901, as follows:

> Find the excavation filled up and the locality so overgrown with brush as to be unidentifiable with exactness. But the same beds reach the surface at a point about one-fourth mile southwest by compass from Fred Wilkins's house on the brow of the hill west of Williamson's place. Here the removal of a few inches of

[1] Pal. Cal., Vol. II, p. 15.

detritus showed a plastic, clayey material, bluish when first exposed, but becoming with exposure a very friable light shale, nearly white, with ferruginous streaks. Owing to the facts that there are no outcrops and the country is overgrown with brake and shrubbery, the distribution of this material can not be stated. No shells are preserved in it, but it presents impressions of *Cerithiopsis*, *Peristernia? Dentalium*, *Amauropsis* or *Ampullina*, a very abundant *Macoma*, *Lepton? Galerus*, *Balanus*, corals, and small fishes. None of the species was recognizable as known in other Tertiary rocks, and the beds may be newer or older than the prevalent Miocene of lower altitudes in the same region. If the naticoid is really an *Ampullina* it would point toward an Oligocene age, but none of the others is characteristic, as far as I know.

The Wymer beds of Diller may have been deposited at the time of the greatest Miocene depression and before the subsequent elevation initiated the erosion which followed. Their fossils, unfortunately, are not characteristic, except that they are not older than the Tertiary.

Dr. Dall's examination of the beds about Crescent City was much more extensive, and his report in the letter noted above is given below in full:

Localities near Crescent City.—South of the long pier at Crescent City the beach is sandy, with no outcrops of rock for half a mile or more. North of the pier, between tides, at the level of the beach and dipping a little seaward, is a very soft bluish sandstone (4) containing pebbles and worn fragments of carbonized wood.

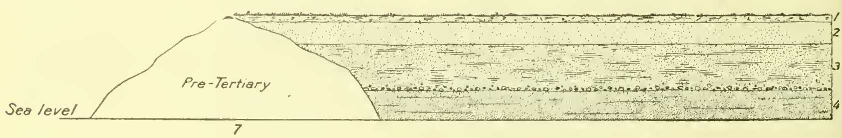


FIG. 5.—Crescent City section at Battery Point.

A few invertebrates occur sparsely, including *Terebratalia hemphilli* Dall, which is known elsewhere only from the Pliocene beds of Santa Barbara. The thickness of this bed below midtide is unknown. Above this lies a bed of yellowish sand and clay (3), about as compact as (4), with a good many included pebbles, especially near the base. It is conformable with No. 4, and shows wave-structure and occasional modifications of color, etc., locally. It contains no fossils, and has a thickness of 6 to 10 feet, rarely more. No. 2 is also nonfossiliferous, slightly consolidated and variable in this respect, and composed of 3 to 5 feet of yellow sand. Between No. 2 and the turf on the east side of Point St. George lies 12 to 18 inches of black kitchen-midden soil containing many fragments of shells (recent species), charcoal, cetacean bones, round pebbles for cracking the shells, and an occasional bone awl, but no weapons or stone implements. Nos. 1 to 4 abut unconformably upon masses of a much altered sandstone (No. 7), which has, in the main, lost its bedding, but in one instance was observed to dip inland 45°. This rock is much contorted and crushed, nearly black, and very hard in places. It contains large fragments of carbonized or petrified wood, apparently *Sequoia*, and dioritic pebbles of various sizes, some very large. Here and there is an intrusion of dioritic rock, or the mass of the sandstone has become crystalline from alteration. Of this hard rock the reefs and islets in Crescent City roadstead and at Point St. George and northward are composed. The large offshore islets show traces of the softer yellow sandstones on their summits in many cases. This rock (No. 7) emerges along the shores northward from Battery Point in many places until the bluffs are interrupted by

the flats about Lake Earl. Unconformably upon it (Station 5339, etc., of Diller, 1900) lies a Miocene sandstone replete with marine fossils, chiefly *Macoma* and *Tapes*. It is massive, and at the bottom where it rests upon the metamorphic rock it contains a multitude of waterworn pebbles, which at the base make up the mass of the rock and grow sparser upward.

These Miocene layers are unconformable with No. 7, but are not horizontal; they are more or less arched over the irregularities of No. 7, and in the longest stretch observed seem to have a dip of 20° to the northward. The upper surface seemed more or less eroded, and upon it lie horizontally the yellow sand beds corresponding to No. 2 and No. 3 of the Crescent City section. I found no trace of the supposed Pliocene No. 4, and it may have been eroded here before the deposition of No. 2 and No. 3. The dikes of No. 7 do not cut the Miocene beds. Near the northwest end of Pebble Beach a low solid mass of fossiliferous Miocene rises 8 to 10 feet above the beach, capped with some nonfossiliferous, soft, sandy layers dipping 27° north and a little east. About 3 feet thick at the farther end, they rapidly increase eastward to about 12 feet visible above the beach, and, losing their lamination, become massive. The Miocene is in sight only a short distance, then passes below the beach level, but the sand beds seem to be more or less conformable with it and are perhaps of nearly the same age. The latter are planed off at the top, horizontal, and the beds 3 and 2, above, being softer, the lower sand bed stands out like a bench between the Miocene point and the roadway up the bluff, at the northeast end of the beach. Beds No. 2 and No. 3 are the same as the beds so numbered in the Crescent City section, nonfossiliferous, sandy or gravelly in different proportions at different localities, but conformable to each other and nearly horizontal, dip-

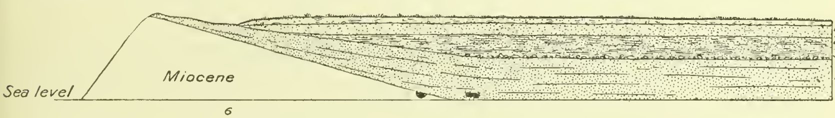


FIG. 6.—Pebble Beach section, 2 miles north of Crescent City, Cal.

ping slightly seaward. The sandstone below them and above the fossiliferous bed may perhaps be the equivalent of the Pliocene bed (No. 4) at Point St. George.

The result of the examination of the rocks of Crescent City is to indicate for No. 7 an unconformity with the succeeding beds formed by an eroded surface, then a cessation of crumpling and dike formation, then, after a depression, the deposition of coarse gravels shading into sandstone of Miocene age, followed by a thin Pliocene layer; then another erosion period, followed by a deposit of unfossiliferous sand in horizontal layers, which has been moderately elevated.

ON MAD RIVER.

A few miles south of Crescent City the coastal plain runs out; the shore becomes abrupt and rocky, and so continues to beyond Trinidad Head, where the broad lowland about Humboldt Bay comes in and at once suggests a large area of soft rocks. By the road, as this large coastal plain is approached, hard sandstones and dioritic and other igneous rocks occur here and there among the sands, gravels, and shell beds of the coast. Ascending Mad River beyond Blue Lake the alluvial plain ends abruptly at North Fork against bluffs of tilted sand beds locally rich in shells. These soft beds form the hills whose flat tops mark the ancient valley of Mad River, up which they extend at least as far as the mouth of Canyon Creek. A bold bluff at that

point exposes about 100 feet of soft, fossiliferous sandstones striking N. 40° W. and dipping 30° NE. The dip of these soft beds wherever seen on both sides of Mad River Valley was to the northeast, as if the mass is monoclinal. At the mouth of Canyon Creek they rest on hard gray sandstones and dark shales, much crushed and twisted, with an average strike of N. 35° W. and dip 75° NE. The soft sandstones are locally lithified by calcareous cement, so that fossils, although generally in sand that is scarcely indurated, in some layers are in hard material. Among the fossils collected from this place Dr. Dall recognizes *Macoma* sp. near *edentula* Sby., *Macoma* near *M. kelseyi* Dall, *Cardium* near *ciliatum* Fabr., *Cardium* near *corbis* Mart., *Macoma* near *expansa* Cpr., *Mytilus* n. sp., and *Mytilus* near *edulis*, and regarded the forms as "?Upper Miocene." Near by, on Montgomery Creek, from beds occurring close to the top of the bluff from which the above-named fossils were collected, we obtained *Mytilus* sp., *Tapes* sp., and *Spisula* sp., which Dr. Dall regards as "?Pliocene."

ON EEL RIVER—FERNDALE AND RIO DELL.

Similar deposits, some of which are tuffaceous, occur along the road at points between Vance and Ferndale, by way of Eureka, but it is in the Eel River region that the series has its best exposure. On the road leading from Ferndale south across Bear Ridge, as pointed out by Professor Lawson, the Wildcat series of soft shales, sandstone, and conglomerate affords an almost continuous section. In the lower portion of the section shales predominate, while sands are most abundant in the middle portion, and conglomerates occur with the sandstone near the top. The beds do not vary greatly in position. Strike N. 75° W. and dip 24° NE. may be given as a close approximation to the general position of the shale, with a somewhat smaller dip for the sandy beds near the top of the series. Fossils were collected from the lower portion of the series, reaching up nearly to the middle, as exposed along the road. Those collected from the several localities were kept separate, but all have been pronounced either "probably Miocene" or "Upper Miocene." The rusty yellow to whitish fine argillaceous sand close to the base of the series is very full of microscopic organisms, which resemble closely in a general way those of the Empire beds of Coos Bay and Cape Blanco.

The same series is well exposed along Eel River, as described by Lawson, from Scotia down the river, and is especially rich in fossils opposite Rio Dell. The soft sandstones and shales strike N. 75° W. and dip 65° NE. On the left bank of Eel River, a little above Scotia, the crushed dark-gray sandstones and shales, most likely of Mesozoic age, are exposed beneath the basal beds of the Wildcat series.

Below Scotia the right bank affords an almost continuous section for several miles. Sandy shales and ordinary argillaceous shales are most

abundant toward the base, and the sandiness of the beautifully stratified series increases somewhat upward to a heavy conglomerate which appears to correspond to those observed on the road a short distance south of Ferndale. The thickness of the strata in the Wildcat series beneath the conglomerate in the Rio Dell section appears to be less than that at Ferndale, but measurements were not made to determine the difference. Overlying the conglomerate is a heavy mass of sandstone which forms a bluff below the mouth of Price Creek. Conglomerate with sandstones occurs beyond this at Alton, forming the bluff of College Hill, and dips gently to the northeast. The form of the terraces in that region, on the road from Rohnville to Hydesville, suggests faulting. These soft beds extend up the Van Deuzen most of the way toward Bridgeville before rising above the river to the hills and exposing the older rocks in the river banks. Upon the hills they extend much farther east, for at Bridgeville fossiliferous fragments are found in the river bed and along the stage road 4 miles farther south, near Burr Creek, at an elevation of 1,350 feet, within a few feet of the underlying Mesozoic rocks. The beds are composed chiefly of sand and appear to dip gently westward. They are probably near the eastern limit of the formation as now exposed, and correspond, at least in that respect, to the Wymer beds farther north. The fossils collected at these two localities in 1889 and also in 1900 were all determined as Miocene species. On the Bridgeville stage road no fossils were seen south of Burr Creek, but above Dyerville a few miles, on Eel River, they occur, and also at many points throughout the long valley of the South Fork of Eel River.

An extensive collection of fossils was made along Eel River from Scotia to the mouth of the Van Deuzen, and those from the various localities were kept separate, so that the paleontologist might have some basis for recognizing differences in horizons. Care was taken to collect only material in place. The fossils collected by Professor Lawson from the Ferndale and Rio Dell sections were identified by Prof. John C. Merriam, and the age of the Wildcat series, on a percentage basis of living and extinct species, was determined to be Pliocene. Considering this subject in his report on the fossils which my party collected in 1900, Dr. Dall remarks:

> The problem as to their age is not easily settled, and a few explanatory remarks may be useful. The standard Miocene fauna of the Pacific coast is that known as the horizon of the Astoria or Empire beds of Coos Bay. We have a good series, the result of many years' collecting at Coos Bay by an amateur. While many of these are new or undescribed, the possession of the series and a careful stratigraphical section of the rocks from which they came leaves no doubt (1) of their position with regard to the Eocene and Oligocene, and (2) of the chief constituents of the fauna. By comparison it is easy to see whether the same species occur in any other series of fossils sent in for examination, without reference to what the proper names of the particular species may be.
>
> On the other hand, the only strictly defined Californian marine Pliocene fauna which has been recorded is that of San Diego, in the southern part of the State.

Now, there is little doubt that during the Pliocene, as well as at present, there was a marked difference between the contemporaneous faunas of the San Diego region and of northern California and Oregon. From these facts it follows that the Pliocene of northern California, if it exists, would be difficult to determine by paleontological comparison with that of San Diego, and might comprise an almost totally distinct series of species. Furthermore, no reliable lists of the Merced (Pliocene) or the Monterey (Miocene) faunas of the middle part of the State have been made public, and the condition of the fossils generally leaves much to be desired.

Lawson has made a study of the geomorphology of the region near Rio Dell, from which the fossils sent by Mr. Diller are largely derived. He regards them as Pliocene. the identifications being due to Dr. John C. Merriam. Paleontologic data alone are of value to determine the relations of a given horizon to the general geologic column. In the present case the fossils comprise a large number of species which are similar to recent forms, and have usually, as in Dr. Merriam's list, been assumed to be identical with the recent forms they resemble. If the determination of age be made by the method of percentages of surviving forms, it is obvious that they will show on these assumptions a percentage sufficient to justify the reference of these beds to the Pliocene, as has been done. On the other hand, if these fossils are merely prototypes and not identical, this will reverse the determination and put the fauna in the Miocene.

I confess to strong doubts as to the specific identity of many of the forms in question with their recent analogues. The Rio Dell fossil fauna contains a certain number of species also found in the Empire beds, and some of the most common species are also common at Coos Bay, but as a whole the fauna is markedly different. It is not only different in the census of species as a whole, but it represents a more northern or colder water assemblage. Indeed, the whole fauna bears a striking resemblance to the existing fauna of the Gulf of Alaska. of which it is beyond question a precursor.

Now, the Alaskan Unga beds and the Oregonian Empire beds agree in possessing many species in common and in having a warm temperate facies. They are doubtless contemporaneous, and certainly Miocene. We have in the Rio Dell fauna, then, a record of a marked change of temperature and an incursion of northern species, because it is not credible that a warm-water fauna could exist in Alaska coincidently with a cold-water fauna in California. I feel confident, then, that the Rio Dell fauna is younger than the Empire beds fauna. On the other hand, the Pliocene of southern California represents much more typical conditions than the subsequent Quaternary or the antecedent southern Miocene, just as the Floridian Pliocene does for the Floridian region. Many species now known only in the Gulf of California lived at San Diego during the Pliocene. It is probable, then, that the presence of the boreal fauna at Rio Dell represents a cold interval between the time of the Empire beds and the Pliocene properly so called.

The fossils of Rio Dell are contained in a sandstone that is usually pretty tough and often very hard. There is no Pliocene fauna known to me which occurs in a rock so indurated as this. Moreover, the color of the matrix is, when unaltered, of the bluish tint which is almost characteristic of the Miocene everywhere in America.

The genus *Lyropecten* is characteristic of the Miocene all over the temperate regions of the globe. A splendid species (*L. dilleri* Dall) occurs at Rio Dell. No *Lyropecten* has so far been reported from any positively Pliocene horizon. This species is the analogue of the *P. madisonius* of the Chesapeake Miocene, as the *P. crassicardo* Conrad of the San Pablo Miocene horizon of middle California is the analogue of the *P. jeffersonius* of the Chesapeake Atlantic Miocene.

On the other hand, some of the species at Rio Dell are identical with species of the Merced Pliocene horizon near San Francisco.

At Crescent City, in a nonindurated deposit, Mr. Diller found *Pecten parmeleei* and *Terebratalia hemphilli*, species heretofore known only from the southern Californian Pliocene. In my opinion this bed must be held to be of the same age as that at San Diego.

To sum up, I incline to the belief that the Rio Dell horizon should be referred to the Upper Miocene; it is certainly younger than the Empire beds, possibly younger than the San Pablo, but older than the Merced horizon.

The determinations of the several localities, beginning at the base of the Ferndale section, are as follows:

5562. North slope of Bear Ridge, by the stage road nearly 7 miles south of Ferndale; elevation 1,950 feet. *Macoma* sp., *Acila* sp., fine brown shale, probably Miocene. 5564 and 5565 are similar, with casts of *Yoldia*, *Neverita*, and fish bones.

5566. Four and one-fourth miles south of Ferndale, on stage road to Bear River. Bed 18 inches thick. Very badly crushed, friable brown shale, with defective casts of *Pecten*, *Yoldia*, *Arca*, *Cardium*, *Siliqua*, *Neverita*, *Tapes*, *Pecten* like *meekii*, *Pecten* like *opuntia*, *Pleurotoma perversa* Gabb, *Neptunea*, *Capulus*, and *Balanus*. Upper Miocene?

In the Eel River section, lying at the base 5574, opposite Scotia; "certainly Miocene—Empire beds probably." 5573, below Scotia, right bank by fording. "Crab remains—Miocene?"

5567–8–9–70. Bluffs opposite Rio Dell. 5576. By slide below Rio Dell. Upper Miocene of Rio Dell. *Pecten dilleri* n. sp., *Yoldia impressa* Conrad (Miocene), *Neptunea altispira* Gabb (Miocene), *Priene* n. sp. (Miocene), *Spisula* (Miocene), *Macoma* sp. (Miocene), *Tapes staleyi* Gabb (Miocene-Pliocene), *Neptunea* n. sp., *Cardium* like *corbis*, *Neverita* (Miocene?), *Bela* sp., *Siliqua* near *lucida*, *Yoldia* near *scissurata*, *Serripes grönlandicus* Beck (Miocene-Pliocene), *Macoma* like *tenera* Leach? *Nassa* near *mendica*, *Dentalium* sp., *Balanus* sp., *Pecten propatulus* Conr. (Miocene-Pliocene), *Marcia* near *subdiaphana* (Olig.-Rec.), *Tresus* near *nuttallii*, but distinct, *Thracia* sp., *Panomya* sp., *Echinarachnius* near *interstriata* Blake.

In this list those noted as Miocene are known from the Empire beds.

5577. Below mouth of Price Creek in Eel River. Crushed fragments in a soft matrix, Pliocene? These include, besides fragments, *Neverita* and *Purpura decemcostata*, not found in older beds. It may even be Pleistocene.

As a result of Dr. Dall's recent examination of the Neocene deposits in the Eel River region, he has furnished the following notes:

Notes on the beds along the "Wildcat road."—At the base of the beach bluff the same basal metamorphic sandstones (No. 7) noted at Crescent City, with numerous small white veins of quartz, calcite, or borate of lime, which are covered unconformably by heavy beds of gravel, perhaps the equivalent of the basal Miocene gravel at Crescent City, occur, but in much greater thickness and mass, while in the places I was able to examine these beds of pebbles and coarse gravel are directly covered with the later alluvium (No. 2 and No. 3) without exhibiting any of the finer grained beds, such as carry Miocene fossils at Crescent City. As in the case of the Crescent City Miocene, they dip gently away from the sea, and are usually arched over the irregularities of the metamorphic sand rock (No. 7). Above the gravels at the north end of the beach bluffs occur the yellow horizontal sandstones (Nos. 2 and 3) noticed at Crescent City. Here they cap the gravels at several points, but are absent in other places.

On the Capetown or Wildcat road the exposures of rock, except in a few places, are poor, and as a rule the beds exposed are either fragmental or not indurated.

No very high dips were observed and nothing which could be called vertical. None of the exposures appeared to be fossiliferous. On the seaward side of the road was noticed an indurated shale, destitute of fossils, in thin layers and much shattered. Next massive beds of fine-grained sandstone like those noticed above the Miocene at Pebble Beach, Crescent City. These dipped about 20° northward, as shown by very thin streaks of fine gravel. Otherwise there was little indication of the bedding. This bed is the thickest and best exposed on the whole section, and so much of it had recently been cut away that it is almost certain that if there were fossils in it they would have been noticed. Apparently above this and northward from it were heavy beds of pebbles with a little fine gravel between them. These pebbles were waterworn and rarely exceeded 3 inches in longer diameter. Still farther south were seen in several places stream gravels containing some heavy bowlders. On the whole, my conclusions from this rapid reconnaissance were that, excepting some projections of the metamorphic sandstone (No. 7) near Capetown, there was nothing along this section which might not be Upper Miocene or later, though a much more thorough study of the details is required before the relations and age of the sands and gravels can be fixed.

Rio Dell and vicinity.—The series of bluffs which border the plain of Eel River from Scotia to the mouth of the Van Deusen were carefully examined. Opposite Rio Dell they consist of irregularly alternating layers of shale and sandstone completely conformable and doubtless the result of continuous sedimentation. They dip N. 30° E. at an average angle of 45°, but are more or less bent or curved in many places, while preserving a general parallelism. In some places the rock has become a tolerably hard sandstone, and these hard layers are usually replete with fossils, mostly bivalves. The shaly layers disintegrate deeply under the influence of the sun, and every year sees a sheet of this disintegrated material several inches thick carried down from the softer spots. At the extreme north end, near the Scotia footbridge, the beds are more argillaceous and soft. The bedding is here very indistinct, and in some places appears to be nearly vertical, as if the end of the bluffs had received the crushing due to a pressure of the beds from the north and east. On the west side of the river, at the so-called Blue Slide, the beds dip nearly N. magnetic about 45°.

At Grizzly Bluff, opposite the end of the bluffs at the confluence of the Van Deusen, 2 miles below Blue Slide, the rock is a massive soft sandstone in beds 6 to 10 feet thick: some beds contain gravel or pebbles and above the base is a heavy bed of stream gravel. The dip is N. 5°–10°, gradually diminishing northward, the strata becoming more gravelly and barren upward. There were no unconformities observed. To all appearances, after examination at several other points, the massive soft sandstones continue with increasing northerly dip up the valley to a point north by compass from the house of Mr. Henry Davis at Rio Dell, where they are conformably succeeded by the softer light-gray shaly sandstones.

In a general way it looks as if the valley had been the scene of rather intense deposition of sand, clay, and gravel from the Upper Miocene to some period in the Pliocene without marked unconformity and with a continuous fauna which changed, if at all, chiefly by some species becoming more rare or disappearing entirely. These sediments were gradually tilted by pressure and more or less crumpled. But the forces exerted were not transmitted far in the line of pressure, but were remarkable by their effects on the periphery of the deposits, portions of which were elevated to the height of the highest existing hills. The uppermost sediments are, of course, younger than the lower ones, but I have seen nothing in the abundant fossil fauna or its distribution to alter my opinion first expressed after an examination of the fossils alone, that the characteristics of the fauna point to an Upper Miocene age and no distinctively Pliocene species of mollusks appear in it anywhere. A large part of the sands and gravels of the more

seaward summits appear very recent and may be Pleistocene, but to fix these accurately and conclusively more lengthened and detailed study will be required than any rapid reconnaissance can afford.

NEAR ROUND VALLEY.

A most important deposit of Neocene beds occurs on Middle Fork at the mouth of Salt Creek, 8 miles southwest of Covelo, Mendocino County. These beds have been described by Mr. Goodyear[1] and others,[2] who give a detailed section of the deposit on account of the coal bed it contains. The coal is about 14 feet thick, strike N. 25° W., dip 25° NE., and lies between fragile shales having a total thickness of about 100 feet. Shells are reported, but their determination is not given.

The same formation extends up Salt Creek for a number of miles. Three miles west of Eden Valley, near the head of Salt Creek, an oyster bed occurs with 20 feet of soft shale having essentially the same strike and dip as that a few miles northwest. It rests directly upon serpentine at an elevation of over 3,700 feet. Fossils from this locality were referred to Dr. Dall, who reports "fragments of a very large oyster and small barnacles of Miocene type, but specifically indeterminable owing to defective state. This locality is especially interesting as representing about the most eastern part at which Miocene marine beds have been detected in northern California." On the map (Pl. I) the approximate coast line of the Miocene is indicated, and it may be seen that practically the whole of the northern end of the Coast Range was then below sea level.

FLUVIO-ESTUARINE DEPOSITS OF TRINITY DRAINAGE.

AT HYAMPOM.

In addition to the purely marine Neocene deposits, all of which lie on the southwest side of the shore line indicated on the map, there are other deposits of brackish- or fresh-water origin whose relation to those occurring nearer the coast is not yet fully known. They occur at Hyampom and Hay Fork, along Hay Fork, which drains into the South Fork of the Trinity, and at Big Bar, Weaverville Basin, Redding Creek Basin, and near Lowdens, all of which are drained by Trinity River. The general distribution of these deposits was outlined some years ago,[3] but fossils lately found have given greater definiteness to our knowledge of them.

Hyampom is at the junction of Hay Fork and the South Fork of Trinity River, at an elevation of about 1,400 feet. In September, 1889, the writer passed that way and observed coal-bearing rocks at one place having a thickness of about 40 feet, with a strike N. 10° to 25°

[1] Coal Mines of the Pacific Coast, p. 74.

[2] State Mining Bureau of California, Twelfth Report of the State Mineralogist, p. 57.

[3] Fourteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1894, Pl. XLV, p. 414.

W., dip 20° to 30° NE. In these beds are two layers of coal and carbonaceous material, one 10 feet thick, the other 5. Toward the top is a bed of volcanic dust 1 foot thick, and 16 feet below it is a much smaller bed. The remainder of the series inclosing the coals and layers of volcanic ash consists of shales, some of which are so finely bedded as to be decidedly laminated. Their reddish color, due to weathering, gives them an aspect of age, and they contain a few fossil leaves. Coal has been found at several points in the valley, especially toward the north end, where Hay Fork enters from a canyon in rocks unconformably below the coal-bearing sediments of the valley. Near the mouth of the canyon the coal-bearing series, which for convenience we will call the Hyampom beds, have an exposed thickness of 250 feet, the upper 100 feet being conglomerate and the lower portion sandy, containing here and there concretions. Some of the sandstones are rather hard, strike N. 85° E., with a dip of 30° SE., and contain coaly beds. Near the base of the series is 25 feet of conglomerate, and the bottom portion, about 30 feet in thickness, is not exposed. The volcanic beds were not found at this point, although the coaly beds are exposed.

The limitations of the Hyampom beds to the valley of the same name, 3 or 4 miles in length and of less breadth, their unconformity with the underlying formation, and their composition and fossils indicate that they are of local origin in a lake, or rather in a ponded stream. Since then they have been compressed and tilted. They lie at the northeast base of South Fork Mountain, over 4,000 feet below its even-crested summit which marks the Klamath peneplain. It is possible that they have been faulted down from near the level of the Klamath peneplain, and, being soft, have led to the development of Hyampom Valley. It is possible also that they belong to a later river stage, but their exact relation to the coastal deposit is not yet known, although it is certain on account of their position that they have been displaced in much the same way as the marine beds of the coast.

Among the fossil plants found at this locality in 1889, Professor Ward recognizes *Taxodium distichum miocenum* Heer, which he says is "abundant in the Arctic Tertiaries as well as those of Europe and elsewhere." It differs so slightly from the living *Taxodium distichum*, our well-known cypress, that it may be expected in any of the later formations, and is therefore of little geognostic value further than to make it probable that the Hyampom beds are not lower than the Tertiary or highest Cretaceous.

This report of Professor Ward was made December 20, 1889. Dr. Knowlton has since given much attention to the Tertiary floras of the Pacific coast, and a letter addressed to him asking for later information brought the following reply, dated January 22, 1901:

Regarding *Taxodium distichum miocenum*, I may say that in only one place in the world, namely, Oeningen, is it known in the Pliocene, and even this locality

is doubtful, for it may be only extreme Upper Miocene. It is mainly a Miocene species, occurring abundantly in many parts of the world, but has also been reported from the Oligocene or even a little lower, in the Eocene. Theoretically it should be found in the Pliocene as well as Pleistocene somewhere, as it is but slightly different from the living *Taxodium distichum*, our well-known cypress. Plant beds in these formations (Pliocene and Pleistocene) are extremely rare.

Concerning the fossils collected for the writer by Mr. Storrs at Hyampom, in June, 1901, Dr. Knowlton reports, December 3, 1901, as follows:

This collection consists of about 25 pieces of thin, yellowish white matrix, in which are preserved apparently four species of fossil plants, as follows: *Sequoia angustifolia* Lesq., *Sequoia langsdorfii* (Brgt.) Heer., *Salix* sp. (large lanceolate, serrate leaf), *Salix* sp. (small ovate-lanceolate, entire-margined leaves). The first of these leaves (*Sequoia angustifolia*) was originally described by Lesquereux from Elko, Nev., and has since been found at Corral Hollow, Cal., and in the Payette formation near Marsh post-office, Idaho. The specimens from Hyampom are absolutely the same as those from Corral Hollow, and should be Upper Miocene in age.

There is only a single example with its counterpart that is referred to *Sequoia langsdorfii*. This is exactly similar to numerous specimens from the Mascall beds of the John Day Basin, Oregon. It is a species widely distributed throughout the Tertiary, but is perhaps most abundant in the Miocene.

The species of *Salix* do not appear to be described, but they are not greatly unlike well-known forms from the Miocene.

We therefore seem warranted in placing the beds containing this little flora in the Upper Miocene

AT HAY FORK.

Sediments similar to those of Hyampom, locally associated with coal, occur farther up Hay Fork, near the town of Hay Fork. According to Mr. Hershey's preliminary map they extend for 10 miles nearly east and west, with a width of about a mile. In these deposits, at a point about 3 miles down the creek from the town of Hay Fork, Mr. Storrs found the sandstones and shales striking N. 10° W. and dipping 35° NE. He collected a number of fossil leaves, among which Mr. F. A. Lucas recognizes some sharks' teeth, and remarks that—

They appear to belong to the genus *Lamna;* more than that it is impossible to say, and this throws little light on the age of the stratum in which they occur, as the genus has a considerable range in time and space. However, they are salt-water species, but liable to occur at the mouth of rivers. I have never seen sharks' teeth so much flattened as these, particularly in view of the soft character of the matrix.

This is an especially important discovery, for it fixes the level at which the deposits originated at about sea level.

Concerning the leaves, Dr. Knowlton says:

This collection consists of some twenty or more pieces of matrix, hard and coarse grained, on which the plants are very poorly preserved. A number of species are evidently present, but owing to the poor state of preservation it is

possible to determine only the following: *Sequoia angustifolia* Lesq. (single specimen), *Salix angusta* Al. W. (numerous specimens), *Quercus* sp. (large leaf, but badly broken), large three-ribbed leaf, but without margin.

The remarks under *Sequoia angustifolia* in the former report apply here. *Salix angusta* also has a wide distribution in the Tertiary, but the specimens under consideration are very similar to numerous leaves referred to this species from the auriferous gravels of California.

The results obtained from the study of this material are far from satisfactory. Only two species, and these of general distribution in the Tertiary, can at present be determined. Relying on their resemblance to material known to have come from the auriferous gravels, it seems not improbable that the Hay Fork beds may be similar in age, namely, Upper Miocene.

REDDING CREEK AND WEAVERVILLE REGION.

Deposits of the same sort occur in the valley of Redding Creek 6 miles southeast of Douglas City. They overlie the fossiliferous Cretaceous rocks of that basin, with strike about N. 65° E. and dip 25° SE. A mass of conglomerate rests upon volcanic tuffs and shale in which some coal has been found, and in the shales occur traces of leaves, among which Prof. Lester F. Ward recognizes a *Ficus* whose age he hesitates to pass upon, although he suggests that the form points to a position lower than the auriferous gravels of Chalk Bluff. The latest researches of Mr. Lindgren[1] indicate that the Chalk Bluff beds are of Miocene age.

By far the largest and most important Neocene river deposit, having a thickness of about 1,000 feet, is in the vicinity of Weaverville, extending northeastward for nearly 20 miles, with an average breadth of over 1 mile, to near Swift Creek. Smaller areas of the same tilted conglomerates, sandstones, and shales of little coherence occur southwest of Weaverville near the Junction City road, at several points on Browns Mountain, and along the Trinity River from a short distance above Lowdens southward for about 4 miles. Large bones and teeth have been reported to the writer by miners from the Weaverville Basin, but definite information could not be obtained so as to fix the place of the fossils. Such fossils are not uncommon in some of the bench gravels of the Klamath and other rivers, but their occurrence in the Weaverville Basin beds is not yet certain.

At Big Bar, on Trinity River, 20 miles directly west of Weaverville, there is a mass of sandstones and shales containing beds of coal having a total thickness of at least 100 feet and an inclination of 35°. No fossils were observed.

It may be assumed with great probability that all the fluviolacustrine or estuarine deposits here considered are of essentially the same age. A striking feature of these deposits of the Trinity region is their inclination. They dip in various directions, but for the most part easterly, and lie far below the general level of the plateau sum-

[1] Jour. Geol., Vol. IV, 1896, p. 885.

mits. In most cases their distribution associates them with streams of to-day, but in some places, especially in the Weaverville belt, they are contiguous to no streams at the present time. If the Trinity River formerly followed this belt, it is evident that great changes have taken place in the drainage since the deposition of these beds.

The tuff found on Redding Creek, as well as that at Hay Fork and Hyampom, appears to be the western extension of the Tuscan tuff, so well developed about the borders of the northern portion of the Sacramento Valley, and furnishes a sharp time horizon over that region,[1] Judging from what is known of the volcanic material and the fossil leaves at Hyampom and Hay Fork, it is most likely that the deposits containing them are Miocene. Strata of essentially the same nature as those of Trinity County, but possibly younger, have been observed in Lake County and described by Dr. G. F. Becker.[2] Fresh-water shells, some leaves, and large bones were found, which Professor Marsh considered as very late Pliocene.

ORIGIN OF KLAMATH AND BELLSPRING PENEPLAINS.

That the Klamath peneplain is one of erosion there is no doubt, for it cuts directly across the structural features, and is equally independent of the wide range in the hardness of the rocks upon which it is developed, but the particular manner of the planation, whether subaerial or marine, and if subaerial, whether due to "peneplanation," as explained by Davis,[3] or to other conditions, as set forth by Tarr,[4] Shaler,[5] and W. S. Tangier Smith,[6] may be questioned. The determining level of erosion in all cases was that of the adjacent ocean, which undoubtedly has been the sculptor of the elevated beaches so well developed at various levels along the narrow belt of land between the present shore and the elevated edge of the peneplain. The sharply defined terraces connected with the elevated sea beaches are generally capped by marine deposits. This is not always the case close to the landward borders, although in some cases deposits near the sea cliff are nearly 50 feet in thickness, with much gravel locally rich enough in gold to afford profitable mines.

Sea cliffs, such as limit the marine deposits on the eastward, and beds of sand and gravel such as are common upon these terraces, have not been observed anywhere upon the Klamath peneplain. Excepting the coastal edge, where the Wymer beds occur, it is entirely devoid of marine deposits, and their absence militates against the view that the Klamath peneplain is one of marine denudation. The broad expanse of the plain stretching across the range, when com-

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, Pl. XLV, pp. 414-419.

[2] Mon. U. S. Geol. Survey Vol. XIII, 1888, p. 219.

[3] Am. Jour. Sci., 3d series, Vol. XXXVII, 1889, p. 430.

[4] The peneplain: Am. Geologist, June 1898, Vol. XXI. pp. 351-370.

[5] Bull. Geol. Soc. America, Vol. X, pp. 245-276.

[6] Bull. Dept. Geol. Univ. California, Vol. II, pp. 155-178.

pared with the narrow belts of the marine terraces along the coast, strongly emphasizes the view that the peneplain is of subaerial origin. This view is supported also by the character of the marine deposits along its border. During a later portion of the Empire epoch the sediments all along the coast from the Columbia River to Humboldt Bay were fine, such as are derived from beaches on the edge of broad stretches of lowland so reduced by erosion that the streams carried only fine sediments to the sea. Such conditions prevailed also when the Wymer beds were deposited. They mark the time of greatest development of the peneplain as a land surface in the Klamath Mountains, and being undisturbed in relative position as far as the peneplain is concerned, they mark approximately the position of the Miocene base-level controlling its development.

The approximate plain which gives to the Klamath Mountains their plateau character may be explained by subaerial erosion with the sea marking its border, but the Bellspring peneplain of the coast range may owe some of its development to submarine erosion, although the greater part, if not the whole, is due to land streams. No evidence has yet been found to show that the northern portion of the Coast Range has been beneath the sea since the tilting of the Miocene beds at the close of the Klamath peneplain stage. The topography of this portion of the range is gently sloped above, descending to steep canyons along the present large streams. Some of its evenness of crests may be due to subequality of interstream spacing, as Shaler and Smith have explained for other regions, but this could not have produced the flat tracts, remnants of the peneplain, which are found on some of the ridges. The rocks here are softer and on the whole more uniform than those of the Klamath Mountains, and as they erode more easily a somewhat more advanced stage of topographic cycle might be expected when compared with the Klamath Mountains, notwithstanding the fact that the latter are a much older land surface.

The Klamath peneplain may have originally been covered by residual deposits of considerable thickness, but if so they have been largely removed, for the character of its surface exposures as compared with that of the earlier valleys to be noted presently is essentially the same, but is strongly contrasted with that of the later valleys.

Stream gravels have not been found so closely associated with the Klamath peneplain as to give strength to the argument regarding its subaerial origin, but they have been found in the earlier valleys corresponding to the Sherwood peneplain at an elevation but little below the Klamath peneplain in the Coast Range. By far the most important deposits of this character belong to the ancient Klamath River and will be noticed more particularly under the heading "Earlier valleys."

AGE OF KLAMATH PENEPLAIN.

That the sediments of the Neocene beds deposited along the seaward border of the Klamath peneplain were derived from the Klamath Mountain region there can be no reasonable doubt. They record a long period of but little relative movement of land and sea, during which the land suffered extensive degradation and was finally reduced approximately to a peneplain. That there were changes of level during the Neocene sufficient to record themselves in a marked change of sediments is clearly shown by the presence of heavy beds of conglomerate among the sandstones and shales at Cape Blanco and later in the region of Humboldt Bay, but on the whole the sediments were derived from land areas of low declivity. The rich fauna and the calcareous nodules suggest the same condition.

The condition which the Wymer beds record is that of the Klamath peneplain just before it was uplifted to initiate the plateau of the Klamath Mountains. The Wymer beds are purely marine sediments, resting upon the very edge of the Klamath peneplain, and now lie practically undisturbed, except for the uplifting to their present altitude of 2,200 feet. They are possibly east of the zone of greatest displacement connected with the final uplifting of the Klamath Mountains.

Beds of nearly the same relative position occur at an elevation of 1,350 feet about the eastern limit of the Neocene beds in the vicinity of Bridgeville. Except where indurated by local deposits of carbonate of lime the beds are very soft and lie undisturbed east of the belt of greatest disturbance of the Wildcat series. According to Dr. Dall, all the fossils found in the Neocene strata about Bridgeville are Miocene species.

While it is certain that the deposition of the Wymer beds and those of the hills about Bridgeville occurred during the Neocene and probably in the late Miocene, its exact geological age can not be fully established without further paleontological study and comparison with the various formations developed about San Francisco Bay and the adjoining portion of the Great Valley of California. The age of the San Pablo beds, of which Dr. Dall has made mention, is not definitely known, or at any rate its fauna has not as yet been fully published. The tendency of the evidence throughout, as far as known, appears to indicate a late Miocene age for the Klamath peneplain, but if on further study the Wymer beds and those of the Hay Fork stage should turn out to be Pliocene or Pleistocene the age of the Klamath peneplain would be correspondingly reduced.

DISLOCATION OF MIOCENE DEPOSITS OF COAST RANGE AND SUBSEQUENT PLANATION.

Although there were slight variations in the relative attitude of the land and sea during the Miocene, as recorded in the change of sedi-

ments, there were no pronounced movements until near its close. The Klamath peneplain had attained its greatest development during the deposition of the Wymer beds, and the period of long-continued relative stability was changed to one of vigorous diastrophism, which resulted in compressing the narrow belt of Miocene sediments of the coast along faults in such way as to give them a general dip northeastward. The dip of the strata is usually from 10° to 25°, but at Rio Dell a thick section of sandstones and shales dips 70°. These high dips are confined to a small portion of the southwestern border of the Eel River area, and the inclination is toward the northeast. The prevalence of northeasterly dips throughout the Mad River area, as well as throughout the greater part, if not the whole, of the Eel River mass, including that of the South Fork and the vicinity of Round Valley, suggests faulting. In general, the amount of disturbance in each area decreases northeastward, so that the greatest displacement appears to be limited to a comparatively narrow belt near the coast. Along the eastern border of the Miocene area the strata were in most places but little disturbed.

The dislocation of the Miocene sediments brought them up to the sea level, but does not appear to have raised to any considerable extent the Klamath Mountain region, for the plain cut upon the soft, tilted, Miocene beds during a relatively quiet epoch immediately succeeding the tilting accords approximately with the Klamath peneplain. The Miocene dislocation must have been accompanied to a large extent by the dislocation of the underlying older rocks. Being near the seacoast, these irregularities were vigorously attacked and were reduced to gentler features showing well-defined marks of baseleveling, but the irregularities of the upland were not all removed before the Bellspring stage was brought to a close by an upheaval.

OROGENIC MOVEMENT INITIATING SHERWOOD STAGE.

The uplift was differential. Near the coast there was but little uplifting; to the east it increased so that the crest of the range was raised nearly 2,000 feet, and the Klamath peneplain was warped and broken to a considerable extent, but not so much as to obscure the essential evenness of the peneplain. In like manner the Bellspring peneplain was somewhat affected.

The uplift at the close of the Bellspring stage initiated that of the Sherwood peneplain. The upturned beds of the Wildcat series were easily removed, exposing the older and harder rocks beneath. The plain extended inland in places under favorable circumstances for many miles. Near the coast, where carved upon the Wildcat series, the plain has an altitude at present only a few hundred feet lower than the Klamath peneplain at the same place. Farther east the difference in elevation between the Klamath and Sherwood peneplains increases, a feature which shows that the uplift closing the Klamath epoch was differential and greatest near the crest of the range.

OROGENIC MOVEMENT INITIATING GARBERVILLE STAGE.

The Sherwood stage was short as compared with the Bellspring and Klamath stages, and was brought to a close by an upheaval which affected the whole Klamath Mountain and Coast Range region. Although of wide extent, the uplift was not great, scarcely 500 feet. The streams were rejuvenated and a new cycle of erosion was initiated in the Garberville stage, which was sufficiently long to enable the streams to carve out broad valleys, especially on soft beds. The stream most favorably situated for widening its valley during the Garberville stage was the South Fork of Eel River. Across the Sherwood peneplain, which was well developed in that region, the South Fork cuts a broad valley nearly 500 feet deep, which is sharply distinguished from the narrow canyon-like valley of the present river.

During the Sherwood and Garberville stages the rivers developed broad valleys, which are in strong contrast with the canyons in which the same rivers now flow, and, to facilitate the consideration of the broader river valleys which are above and older than the canyons, they are grouped together under the general designation "Earlier valleys," while the canyons are the "Later valleys."

EARLIER VALLEYS.

The lines of drainage during the development of the Klamath and Bellspring peneplains, the changes introduced by the subsequent

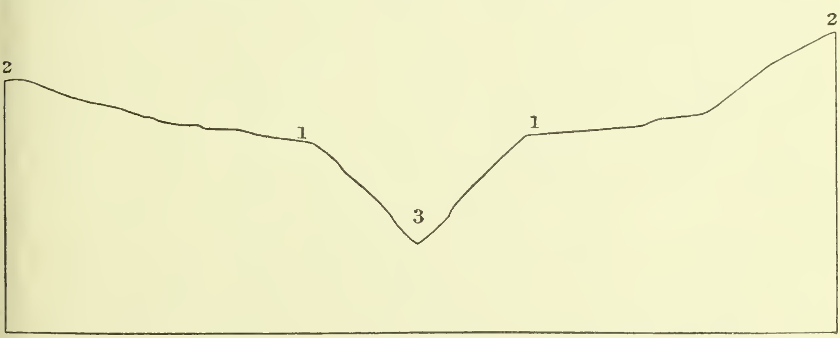


FIG. 7.—Section showing relation of earlier valleys to Klamath peneplain and later valleys.

uplifts, as well as the progressive changes in adjustment as the topographic cycles advanced after each change of level, furnish a most inviting field for investigation, but these can not be satisfactorily worked out and described without much more detailed topographic surveys.

The term "earlier valleys" is used to embrace especially those corresponding to the Sherwood and Garberville stages. They generally form a marked feature of the upland, but the valleys of these two stages can rarely be clearly distinguished. The general relations

of the earlier valleys (1) to the Klamath peneplain (2) above and the later valleys or canyons (3) below is shown in fig. 7.

It should be understood, however, that the gentle features of the earlier valleys are not all of the same age. They have their terraces at various elevations, often due to local obstructions or minor oscillations, but as a whole they may be taken as marking a long time or long times of relative stability, especially the Sherwood and Garberville stages, permitting the development of wide valleys with gentle features. Nearer the sea, and in some measure under its influence, the Sherwood peneplain was formed. At a much later stage the 1,000-foot terrace was developed, and it marks, approximately, the levels upon which the various earlier valleys terminate.

EARLIER VALLEY OF UMPQUA RIVER.

From Coles Valley the Umpqua flows along the eastern foot of the Coast Range to the sea in an extremely winding course, a feature which it appears to have acquired during the final stage of the development of the Klamath peneplain. This serpentine course was preserved during the cutting of the earlier valley as well as the later. The earlier valley of the Umpqua is well marked only across the Coast Range, where it is preserved in the massive sandstone. Eastward, in the Roseburg region, the beds are softer and the ancient records have been largely destroyed.

Near Tyee Mountain, where the river enters the comparatively hard rocks of the range, the earlier valley is not so extensively developed as it is farther northwest. From the hills southeast of Elkton, where the river turns directly west to the sea, the plain of the earlier valley has a width of at least 6 miles and is very uniform at an elevation of nearly 1,300 feet. Its sides are seen in the distance and are not conspicuous. They are rather irregular, as if in the uplifting or subsequent erosion the older Klamath peneplain had been modified. The best general view of the earlier valley of the Umpqua, and especially of its relation to the late valley, may be obtained from a summit 1 mile west of Scottsburg at an altitude of 1,210 feet. The floor of the old valley is remarkably even, although cut across hard and soft rocks inclined at a considerable angle, and is in strong contrast with the later valley, which is, in general, a narrow canyon over 1,000 feet deep. The earlier valley is rather densely wooded, and the settlers along the river are confined almost exclusively to the narrow alluvial plains by the river in the canyon of the later valley.

EARLIER VALLEYS OF COOS AND COQUILLE RIVERS.

The soft rocks in the Coos Bay region have not preserved the ancient landmarks near the coast, but 15 or 20 miles back from the coast earlier valleys, both of the Coos and of the Coquille, may be found at an elevation of 1,500 feet. Farther east these old valleys

rise; that of the East Fork of the Coquille at Lairds has an altitude of over 2,000 feet and affords a fine view of the adjacent edges of the Klamath peneplain.

EARLIER VALLEYS OF SIXES AND ELK RIVERS.

South of the Coquille the rocks of the irregular complex below the Eocene come to the surface, giving rise to greater irregularity in the topographic features.

On Sixes River the earlier valley was well developed not only along the main stream but also along the principal forks. From a sharp crest northeast of the trail crossing from Sixes to the mouth of Edson Creek a fine view up the old valley of the Sixes may be obtained at an altitude of about a thousand feet. Farther west, a little below this level, on both sides of the river there is an extensive terrace capped by the highest marine sands noted in the region. The earlier valley ends in this terrace, suggesting that the two are contemporaneous, but it seems more probable, from facts considered elsewhere, that the terrace is much younger than the "earlier valley."

Farther up the Sixes the early valley bottom near Elephant Rock has an altitude of 1,200 feet. Looking toward Eckley from Elephant Rock one of the finest views of this old valley may be obtained. Opposite Mount Avery it has a depth of nearly a thousand feet below the level of the peneplain.

The broader valley about Eckley is due to the basin of softer Eocene sediments. On the South Fork of the Sixes, between Mount Butler and Mount Avery, the old valley at an altitude of 2,000 feet is shallow, being but a few hundred feet below the general level of the peneplain. Here the abrupt change of slope to the canyon of the late valley, 1,500 feet deep, is conspicuous. Farther east, about the headwaters of this stream, the plain of the early valley is much wider, with gentle slopes to the level of the peneplain.

On Elk River a few miles south of the Sixes the conditions are much the same, but the early valley is not so well preserved, chiefly on account of the large number of landslides, due in part, apparently, to the killing of the timber by forest fires. All the timber for many square miles has been killed.

EARLIER VALLEY OF ROGUE RIVER.

From the south of Bald Brushy Mountain and First Prairie Mountain a good view can be obtained of the earlier valley of Rogue River. On the south bank of the river, a few miles above the mouth of Silver Creek, is a flat-topped hill, a portion of the old valley bottom, having an estimated elevation of nearly 2,000 feet. On both sides the valley has a gentle slope rising from that elevation and marking the general outline of the earlier valley, in strong contrast with the canyon below. The earlier valley of Rogue River, although larger, is less sharply marked than that of the Sixes.

EARLIER VALLEY OF KLAMATH RIVER.

Between Rogue River and the Klamath, Pistol River and Chetco River in Oregon, and Smith River in California, are the only streams of considerable size, and they all show traces of wide valleys above the newer canyons in which the rivers are now flowing.

Klamath River, heading east of the mountain belt on the low border of the Great Basin, breaks through the Cascade and Coast ranges to the sea. The Klamath peneplain crosses the range between the Siskiyou Mountains and the rugged peaks about the head of Salmon River, and at this point is traversed by Klamath River, whose earlier valley is well marked in places, as, for example, near Happy Camp, where the even crests of the spurs and ridges adjoining the canyon are clearly observable. As one ascends to get a general view the evenness of the hills becomes more pronounced, and it is apparent that here, as on the Umpqua, there is a wide old valley of the river above the canyon in which it now flows. One of the best points from which to view this feature, in the region noted above, is about $2\frac{1}{2}$ miles S. 40° W. of Happy Camp, from a point on the north bank of the river, at an elevation of 3,800 feet above the sea or 2,000 above the river. Looking east up the earlier valley of the Klamath, one sees that its limits are marked by the bordering uplands, where traces of the Klamath peneplain may be clearly seen. The earlier valley is wide at this point, where it traverses rather soft shales and schists in which the late valley (canyon) also widens, and affords benches for mining and agriculture.

Down the river the earlier valley of the Klamath is well marked above the mouth of Salmon River at an altitude of about 4,200 feet. The altitude of the valley at Happy Camp, about 60 miles farther up the Klamath and somewhat farther east, is only 3,800 feet. It is possible that the observations were not made upon levels of the same age, but although attention was given to the matter at the time, no difference of age could be made out. If this is the case, as seems probable, an interesting conclusion may be drawn from their present relative altitudes. The valley level observed near the Salmon at the time of its origin must have been below that of the one near Happy Camp, but as it is now higher the Salmon region must have experienced greater uplift than that at Happy Camp. This differential uplifting accounts, in a measure at least, for the prominence of the Klamath Canyon of the Salmon region.

The same valley was seen again from the northern portion of the Hoopa Indian Reservation between Pine Creek and Trinity River upon a flat-topped mountain. At this point the ancient gravel bed of the earlier valley of the Klamath where entered by the Trinity is remarkably well preserved at an elevation of 3,000 feet (about 2,850 feet above Hoopa Valley), and may be traced along the even crest of an adjacent ridge directly to the coast at Gold Bluff. The Govern-

WILDGRASS RIDGE, CAPPED BY GRAVEL BED OF THE ANCIENT KLAMATH RIVER.

Looking N. 75° W., from near north line of Hoopa Reservation.

ment road to the north end of the reservation is upon this old stream bed for nearly a mile. The gravel is well rounded and many of the pebbles are as large as 4 inches in diameter. The gravel rests upon slates, which form a prominent hill between Hoopa Valley and Klamath River. From this ancient stream bed the gentle slopes of the old valleys rise to the peneplain

Only the surface of the gravel deposit was seen, so that no definite idea of its thickness and structure could be obtained. Its position too, so near the junction of the two rivers, raises doubt as to whether it is really a bit of the old Klamath River bed or belongs to the Trinity, but this is of small moment, for being practically at the junction it may be used in determining the ancient level of both streams. Both streams had corresponding earlier valleys merging at this point.

From this point the divide west of Klamath River to the coast at Gold Bluff is capped by gravel and marks the ancient bed of the Klamath. It was then approximately parallel to its present course, almost directly northwest from the Hoopa Reservation. The writer did not follow it all the way, but has been informed by a number of miners that the deposit is continuous. Along Prairie Creek by the coast road, opposite Gold Bluff, it is exposed upon the flat summit at an altitude of nearly 700 feet.

The Gold Bluff beach has long been celebrated for its rich auriferous sand and gravels, and affords fine exposures of the associated rocks. The oldest is an altered shale containing calcite in blotches and streaks and quartz in short veinlets.

Resting[1] on the shale, which is about 500 feet thick, is gravel, and it extends to the top of the mountain, some 2,000 feet above sea level. Immediately below Butler Creek the black shale disappears below the surface and on it lies a bed of very crumbly gray sandstone 150 to 200 feet thick, a vein of lignite 6 inches thick, and soft, gray, clay shale 80 feet thick. The whole dips 80° S. Nonconformably upon these beds lies the gravel, dipping 15° S. for a short distance, and then assuming a horizontal position. Near the bottom it is slightly cemented, while higher up it is not. The gravel bluffs stand nearly perpendicularly and are from 100 feet to 175 feet high. Going south along the beach 1½ miles the bluffs gradually change. The gravel becomes finer and the percentage of sand increases. Bands of soft gray sandstone appear and grow thicker as we go south. Above the buildings of the Pioneer mine a section shows from the bottom upward as follows:

	Feet.
Gravel, slightly cemented	10
Very soft blue sandstone	15
Gravel, slightly cemented	30
Very soft blue sandstone	10
Small gravel and sand	85

The bluff maintains the same character 3½ miles down the coast, to a small lagoon, where the works of the Union mine are located. Below the lagoon for three-fourths mile the bottom stratum of clay shale is visible, carrying here and there pieces of

[1] State Mining Bureau of California, Thirteenth Report of the State Mineralogist, p. 172.

lignite and nodules of limonite. The bluffs are low, 10 to 60 feet, and dip 20° SW., or into the ocean.

There can be no question that these gravels are derived from the ancient bed of Klamath River, but near the coast they may have been worked over and dropped to lower terraces. So far as the writer is aware, fossils have not been found at Gold Bluff, either in the gravels or in the unconformably underlying beds containing carbonaceous material tilted at a high angle. Judging from their position and composition, it is probable that the strata underlying the stream gravels are of Miocene age.

Looking a little north of west from the road near the northern boundary of the Hoopa Reservation, one sees Wildgrass Ridge (see Pl. XII), which is capped by the old channel of the Klamath. It appears to be somewhat higher than the reservation gravels, and may have been elevated by a fault which turned Klamath River along its eastern base.

EARLIER VALLEYS OF REDWOOD CREEK AND MAD RIVER.

Crossing the divide west of Hoopa Valley to Bairs, traces of gravel in the bed of the early valley of Redwood Creek were found at an elevation of 2,550 feet and nearly 2,000 feet above the stream. The early valley is marked also farther northeast, where crossed by the Hoopa wagon road, as illustrated in Pl. XIII.

Fog and smoke greatly interfered with general views, and especially with those of the Mad River country. Nevertheless, its exceptional character was discernible. Seen from the Hoopa road, between Korbel and Acorn, there are terraces in the earlier valley of Mad River at an elevation of 1,600 feet, although a well-developed old valley with rather flat bottom 3 or 4 miles in width is marked by an elevation of nearly a thousand feet.

Just above the town of Blue Lake the North Fork enters Mad River and the broad lowland is limited by bluffs exposing tilted beds of sand locally rich in fossils. Ascending to the summits of these hills, one finds them to have flat tops which rise to an altitude of about 800 feet above the sea, and which form the bottom of an ancient valley of Mad River a number of miles wide. The soft fossiliferous beds extend up the old valley at least 6 miles and afford an explanation of the development of a broad valley at a much lower level than the valleys of the streams already noted. The earlier valley of Mad River, corresponding to those here considered, is marked on the Hoopa road at an elevation of 1,600 feet. The valley at 800 feet is of later date and connects with a broad terrace along the lower course of Mad River. The preservation of these soft beds is due, in part at least, to the fact that by some accident Mad River was turned onto the older and harder rocks, in which it now occupies a canyon along the southern edge of the valley at the 800-foot level.

EARLIER VALLEY OF REDWOOD CREEK ABOVE REDWOOD HOUSE.

Elevation 3,050 feet.

EARLIER VALLEY OF EEL RIVER.

Eel River is next to the Klamath in size among those in northwestern California, and the history of its struggles in developing its present valley would form a most interesting chapter, but for the present only a few of the features will be noticed. Like Mad River, Eel River has its lower course in a thick series of soft sediments deposited along the edge of the Klamath peneplain during its development. In the case of Eel River, however, remnants of the earlier valley are still preserved in the soft beds of the Wildcat series which occur in the flat-topped hills on the western slope of Bear Ridge, at an altitude of about 1,000 feet. The valley was so filled with smoke during the writer's visit that a satisfactory view of its form from Bear Ridge could not be obtained. While the 1,000-foot level was well marked in places with terraces of the soft beds rising even to 2,000 feet, the general distribution of the 1,000-foot level along that part of Eel River could not be as completely determined as was desired. The divide between Rio Dell and Hydesville bears a well-marked plain cut on highly inclined strata, rising about 850 feet above sea level. Near the coast the plain descends to 700 feet as a well-marked terrace. This is evidently the plain corresponding to the one so well marked on the soft beds of Mad River opposite Korbel.

The valley of Eel River was crossed about 50 miles above its mouth, between Blocksburg and Harris, where the earlier valley is not so well marked in contrast with the late one. At this point the river is crossed by a bridge in a canyon only a few hundred feet deep. The river at the bridge is only about 500 feet above tide, and above a relatively small canyon the sides of the valley are rather gentle. Farther upstream they become much steeper, and the valley becomes canyonlike to an altitude above the river of approximately a thousand feet. Along the road leading northwestward, at an altitude of 1,500 feet an ancient valley level is marked.

Farther upstream Eel River was crossed twice on the road from Ukiah to Laytonville by way of Covelo. At Eden Valley and Round Valley on this route there are several local levels of wide extent about 500 feet apart. Their development may indicate the presence of a large mass of soft Miocene rocks, remnants of which have already been noted as occurring on Salt Creek and along the western border of Round Valley. Eel River at the ferry on the Eden Valley road is 725 feet below Round Valley and has an elevation of 1,450 feet above sea level. It flows in a valley with slopes becoming steeper farther downstream, where it is crossed by the road to Laytonville. Near the last crossing the earlier and later valleys are well marked. The later valley has slopes of 41° and is 1,000 feet deep, while above them the slopes decline to 11° and the relief features become much less bold.

On the South Fork of Eel River there is a great development of soft Tertiary strata which have been leveled to the Sherwood peneplain.

Across this plain there was cut, with more or less distinctness, a broad valley before the uplift which resulted in the cutting of the present narrow stream valley. As the earlier valley was seen from the Garberville road on the way to Shelter Cove, the stage of development has been called the Garberville stage.

EARLIER VALLEYS OF RUSSIAN RIVER AND CACHE CREEK.

Beyond this point Eel River was not crossed again, and at the crossing of Russian River and Cache Creek the earlier valleys were not especially noted. In ascending Bartlett Mountain, however, from Upper Lake a well-developed terrace was found at from 3,000 to 4,000 feet, about 1,600 feet above Upper Lake post-office.

EARLIER VALLEY OF STONY CREEK.

Prominent traces of the earlier valleys, such as are found along the rivers of the western slope of the Klamath Mountains, would hardly be expected along the small streams of the eastern slope, and yet in places there are broad plains recording an important valley stage between the completion of the Klamath peneplain and the present time. These are clearly due to soft rocks—shales—for on the harder rocks—sandstones and conglomerates—along the same streams the plain is not developed. The most important plain of this nature is along Stony Creek, in the southwestern part of Glenn County. About the town of Elk Creek, where Elk, Bristo, and Grindstone creeks enter Stony Creek, there is a broad plain extending from Elk Creek Ridge to the base of the Coast Range and having an altitude of about 850 feet above the sea. This plain may be seen to advantage from the slope of Elk Creek Ridge, looking north. On the left is the Coast Range and on the right are the even-crested hills of Stony Creek which mark the Klamath peneplain. The streams from the mountains cut canyons across the Stony Creek plain to the depth of 100 feet, but Stony Creek, a larger stream, has developed broad flood plains about 50 feet below the general level of the plain.

Ten miles north of the town of Elk Creek Stony Creek enters the even-crested foothills capped by the Klamath peneplain and cuts a canyon through them to the alluvial plain of the Sacramento. Farther northward, near Newville, on the same belt of shales, a plain corresponding to that of Elk Creek has been developed. The large size and sharpness of these plains indicate that they most likely record an attitude of the land and are probably not due to a level of local obstruction in the canyon of Stony Creek. On the divide at Millsaps between Elk Creek and Newville is a remarkable terrace which lies between the two plains. Earlier and later valleys of small depths have been seen on Thomas Creek, in Tehama County, but farther northward they have not been clearly distinguished.

SUBSIDENCE AND EARLIER VALLEY FILLING.

It is evident that to fill the old valleys with deposits which are estuarine, at least as far inland as Hay Fork, where sharks' teeth were found, as noted under "Fluvio-estuarine deposits of Trinity drainage" (p. 43), there must have been a subsidence. Hay Fork lies 100 miles from the mouth of the Klamath, but scarcely a score of miles from the crest of the range where crossed by the stage road to the Sacramento Valley. Streams were ponded by the subsidence, and swampy conditions prevailed to preserve the carbonaceous material for the coal beds found at so many points in these deposits, and this condition, with fluctuations, must have obtained for a considerable interval, allowing the old valleys, as that of Weaverville Basin, to fill to great depths.

UPLIFT AND DISPLACEMENT CLOSING EARLIER VALLEY STAGE.

The earlier valley epoch was brought to a close by an epeirogenic uplift of approximately 900 feet all along the coast of the Klamath Mountains, but increasing eastward to a number of times that amount along the crest of the range. It is possible that during uplift the fluvio-estuarine deposits of the earlier valleys were displaced, for in most localities they dip at considerable angles and lie in deep valleys. How much of this depth is due to faulting and how much to earlier stream cutting is not known. The fact that the widest portions of valleys are carved out of these soft disturbed strata indicates that the valley enlargement is due to the soft strata and that the canyon cutting in the older rock is of later date. By the disturbance which tilted the fluvio-estuarine deposits the streams in many places were turned from their old channels and, as the uplifting progressed, cut valleys in new places, while elsewhere they swept the Miocene deposits from the older valleys. This recarving of the old valleys and new canyons was largely accomplished before the Glacial epoch, as is shown by their relation to glaciated areas.

POST-MIOCENE ELEVATION.

The unconformity at Cape Blanco (Pl. IX and fig. 4) indicates a post-Miocene surface of erosion extending below sea level. The age of the overlying beds (No. 6, fig. 4) is now regarded as Pleistocene, allowing the break to represent a considerable time interval. The absence of the Pliocene at that point indicates that it may have been above the sea during that epoch.

At Crescent City essentially the same unconformity is visible, but is much more definite in its time relations. According to Dr. Dall—and my observations are in complete accord with his—the Pliocene of Battery Point rests directly and with a marked unconformity

upon sandstones which are possibly Mesozoic. Although Miocene is well developed a short distance farther up the coast, it was completely removed at this point before the deposition of the Pliocene, indicating an epoch of elevation and erosion between the Miocene and Pliocene. The extent of the erosion during this interval is unknown, but, as already pointed out by Le Conte,[1] there are indications of submarine valleys extending seaward from the present coast to the continental border,[2] and it is possible that they were cut at this time.

GLACIATION OF LATER VALLEYS.

The later valleys, as already noted, are often canyon-like, especially near the valley bottom and the coast. Toward the headwaters the valleys are generally shallower and more open, and have an aspect of greater age than the portion near the coast, and yet their difference in age is probably so small as to be scarcely measurable in geologic time.

Tracing the larger streams up into the Siskiyous, the Yallo Ballys, or the rugged peaks about the head of Salmon and Trinity rivers, one finds the valleys to be glaciated to an unexpectedly large extent. On the northeast slopes of both North and South Yallo Bally Mountains, near the line between Tehama and Trinity counties, Cal., there were formerly glaciers a number of miles in extent which have left well-defined records in striated and polished rocks and ground moraines, with small lakes and meadows above terminal embankments. These ancient glaciers are represented to-day by large snow banks, resulting from the protection which the mountains afford against the driving southwest winds of the winter storms.

Important ancient glaciers among the mountains about the head of Salmon and Trinity rivers have been noted by Mr. Oscar H. Hershey.[3] The largest of these—Swift Creek Glacier—is described as follows:

> At its maximum extension this glacier had a length of not less than 15 miles, a width of ½ to 1 mile, and a depth of 1,000 to 1,500 feet. It was the largest single mass of ice, so far as I know, of the Sierra Costa Mountains. It headed among the peaks in the highest portion of this range, at an altitude now about 6,500 feet, trended in a northeasterly direction, forming the broad flat of the Mumford Meadows (altitude 5,500 feet), then ran southeasterly, descending rapidly to a level now little more than 3,500 feet above the sea, where at 10 miles from its head it suddenly issued from the high mountains and, turning to the northeast, deployed upon and across a broad basin valley of Miocene age and later,[4] and terminated very close to the site of the Redding and Trinity Center road, at an elevation now no greater than 2,500 feet above the sea.

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[1] Bull. Geol. Soc. America, Vol. II, p. 325.

[2] Lawson (Bull. Dept. Geol. Univ. California, Vol. I, pp. 57-59) regards these as due to faulting, and not to erosion.

[3] Jour. Geol., Vol. VIII, 1900, pp. 42-57.

[4] This valley is the northeastern extension of the Weaverville Basin (see page 44).

The amount of erosion which has taken place in the glaciated region, not only in the Klamath Mountains, but also at many other points in Oregon and California, since the ice disappeared, is very small, so that the glaciation of that region has been relegated generally to a late portion of the Glacial epoch.

The bearing of this glaciation upon the age of the younger valleys is direct, and indicates that the river valleys were cut out almost to their present extent at least as early as the later portion of the Glacial epoch.

There is another bit of evidence bearing upon the age of these later valleys which should be mentioned. On the North Fork of Coquille River, 3 miles northeast of Myrtle Point, Coos County, Oreg., a fragment of a mastodon's tusk was found buried in alluvium close to bed rock within 5 feet of the river. According to Mr. Lucas, the piece of tusk is of a form having a peculiar enamel band, and is probably of Pliocene age. Other bones have been found in the same locality, and it is the opinion of the writer, who examined the deposit, that the bones have not been transported far from their original deposit. The tusk gives rise to a suggestion that even the later valleys were practically completed in Pliocene time.

SUBSIDENCE ALONG OREGON COAST.

Concerning the oscillations and subsidence after the continental border stage and the reelevation during the marine terrace stage enough has been said in the brief summary at the beginning of the paper, but concerning the subsidence along the coast of Oregon more facts should be given.

Tide water runs up Rogue River about 4 miles from its mouth, and to about the same extent in all the important rivers south of it at least as far as Cape Mendocino, but in the opposite direction the relation of river to tide level is very different. In Coquille River the tide runs up to the mouth of the North Fork, a distance of over 30 miles. Formerly it ran up farther, but by aggradation the stream has shortened the tide run by nearly 4 miles. In Coos River the tide ascends nearly the same distance. In the Umpqua it goes up at least 25 miles, to Scottsburg, penetrating much farther into the Coast Range at that point than anywhere else south of Columbia River, where it goes up to Cascade Locks, a distance of 150 miles from its mouth. In the smaller streams between the Umpqua and Columbia the ascent, which is less extensive chiefly on account of the smaller size of the streams, being in all cases roughly proportional to the erosive power of the stream, is as follows: Nehalem, 13 miles; Tillamook, 7 miles; Nestugga, 7 miles; Little Nestugga, 8 miles; Siletz, 21 miles; Yaquina, 28 miles; Alsea, 14 miles; Siuslaw, north fork, 11 miles; Siuslaw, main stream, 28 miles.

This tidal transgression has been regarded as indicating that the coast has subsided. That such is the case is shown also by the fact that the rocky beds of the stream are now far below tide level. Borings have been made on the borders of Isthmus and Kentuck sloughs, and the slough muds were found to extend down at least 200 feet below tide—possibly much farther—indicating that at some former epoch that part of the country stood at a higher level than at present, enabling the streams to cut out the portion of the valley which is now submerged. The extent of this subsidence is not definitely known.

RELATION OF KLAMATH PENEPLAIN TO THAT OF SIERRA NEVADA AND COAST RANGE.

On the eastern side of the Sacramento Valley lies the Sierra Nevada, whose long, gentle slope to the valley presents a remarkable plain of erosion. Much has been written concerning this feature, but one of the latest and most noteworthy contributions is by Mr. Lindgren,[1] who recognizes in it two plains of erosion, the one which is most complete consummated just before the deposition of the Chico[2] (Cretaceous), the other during the Miocene. Mr. Lindgren says:[3]

> The relation of the two eroded surfaces, the Cretaceous and the Miocene, is clearly discernible from any point in the lower foothills looking up toward the summit of the range. Above the deep canyons of the modern gorges extend the broad; flat lava plateaus, capping the separating ridges and looking very much like an old base-level. These lava flows cover the comparatively gentle topography of the Miocene valleys. Above them rise the peaks and ridges just mentioned, and indicate with their level sky line the extent of a far older eroded surface uplifted and dissected long before the auriferous gravels were deposited or the lava flows extruded.

The Cretaceous age of the earlier plain pointed out by Lindgren finds support in the character of the Cretaceous sediments of the Sacramento Valley. On the western side of that valley the Lower Cretaceous beds are mostly fine shales with calcareous nodules and are of great thickness, indicating a wide range of low land as their source. During the Chico, which immediately followed, there was an epoch of marine transgression and possibly greater land declivity, for near the base of that series is a heavy conglomerate which can be traced for many miles about the borders of the Sacramento Valley. The final sediments of the Chico were such as to indicate low relief.

The condition of the Klamath Mountain region during the progress of the Cretaceous is not yet fully understood, owing to the fragmentary nature both of the Cretaceous deposits and of our knowledge of them. However, the known distribution of the Cretaceous rocks among the Klamath Mountains, taken together with the border of Cretaceous sediments which may be traced almost continuously around them, indicates that during a late part of the Cretaceous

[1] Jour. Geol., Vol. IV, 1896. p. 881. [2] Idem, p. 894. [3] Idem, p. 897.

the Klamath Mountain region was largely, if not wholly, submerged. This conclusion is sufficient to show that if a Cretaceous peneplain is found anywhere in the Klamath Mountains it must be limited to the summits of the high peaks.

On the other hand, it appears very probable that the Klamath peneplain corresponds to the Miocene plain[1] of the Sierra Nevada. The Miocene age of each plain appears to be fairly established by paleontologic evidence, and their continuity is suggested not only by their juxtaposition but by their fossil flora. Differences in amount and character of deformation, hardness of rocks, climatic conditions, nearness to the sea, and probably also time of elevation may be cited to account for differences in stage of topographic development since since the peneplain was uplifted.

RELATION OF TOPOGRAPHY OF KLAMATH MOUNTAINS AND COAST RANGE.

The topography of the northern end of the Coast Range may be said to be mature. But this is true only on account of the gentle relief above the canyons. The same is true of the topography of the adjacent Klamath Mountains, and yet the cycle appears somewhat less advanced and the canyon stage more profound than in the Coast Range. This difference may be attributed to—

1. Differences of composition. The Coast Range is composed chiefly of Mesozoic sandstones and slates, but among these are numerous though generally small masses of a basaltic intrusive and chert, as well as glaucophane and other very local schists. The rocks, for the most part, have been crushed to small fragments, and are therefore comparatively easily eroded. They were once capped by Neocene sediments of still greater softness, and they played an important rôle in the early cycles of the Coast Range. On the other hand, the Klamath Mountains are composed of much older rocks. Large masses of schists and slates, with some limestones and igneous rocks, such as peridotite, serpentine, gabbro, and diorite and allied forms, are abundant and cover large areas. These rocks are in general much harder than those of the Coast Range, and it would not be expected that the topographic development would be so far advanced.

2. The position of the terranes with reference to the direction of drainage has much to do in determining the degree of relief. In the Coast Range the drainage is largely parallel to the strike of the formations. Wherever the streams cut across the strike they flow in more prominent canyons. In the case of the Klamath River, especially the part from the mouth of the Trinity to Happy Camp and beyond is across the schistose structure, a feature which contributes no small amount to the boldness of the scenery.

[1] Tertiary revolution in the topography of the Pacific coast; Fourteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1894, pp. 397-434.

3. The differential uplifting, always in favor of the crest of the range, across which the Klamath River has long continued to cut its way, has given the Klamath River and headwaters of other streams relatively not only much greater cutting power, so far as grade is concerned, but a larger amount of work to do, and for this reason their canyons are more profound and the topographic cycle is less advanced than in the Coast Range, where the streams, having greater volume, reduced the country more rapidly.

Notwithstanding minor differences, the topographic continuity of the Coast Range and Klamath Mountains is pronounced. Of the two the Klamath Mountains are the older, although in a measure, for reasons given above, less advanced in the cycle of erosion than the Coast Range.

SUPPLEMENT.

NOTES ON THE GEOLOGIC AGE OF SOME OF THE ROCKS OF THE KLAMATH MOUNTAINS.

The Klamath Mountains were early recognized by the Geological Survey of California[1] as composed of rocks essentially the same as those of the Sierra Nevada, and definite horizon determinations began in the eastern extension of the group in Shasta County with the Carboniferous. H. W. Fairbanks,[2] Charles Schuchert,[3] and others,[4] but more especially J. P. Smith,[5] greatly extended the recognition of definite horizons in the same region, but the higher portions of the group in Trinity County have received less attention. Concerning that district, however, we have a comprehensive paper by Mr. O. H. Hershey,[6] who has kindly supplemented it by furnishing me a manuscript copy of his preliminary map of this region, based on the Punnett Brothers' sectional map of Trinity and bordering counties. The oldest formations recognized are a series of mica- and hornblende-schists, which are succeeded by a mass of slates, in part radiolarian, and limestones, all of which are more or less intimately related to a wide range of plutonic and volcanic rocks.

The oldest fossiliferous rocks[7] yet recognized in the region are Devonian, and have been found in a belt at the eastern base of, and in, the Scott Mountains west of Gazelle, Cal. The belt extends southward more or less continuously by the well-known Kennett locality to the northern end of the Sacramento Valley near Horsetown. Northward from Gazelle they have not certainly been recognized. In a limestone 3 miles northeast of Kerby, Josephine County, Oreg., a number of fossils were discovered, but their affinities could not be definitely determined.

West of this belt Devonian rocks have not been recognized with certainty, so far as the writer is aware, unless it be at Three Creeks, on the road to Hoopa Valley, in Humboldt County. These are, however, nearly in line with the supposed Juratrias limestones southeast of Hyampom.

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[1] Geol. Survey California, Vol. I.

[2] Bull. Geol. Soc. America, Vol. VI, p. 71.

[3] Am. Jour. Sci., 3d series, Vol. XLVII, p. 416.

[4] Fourteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1894, Pl. XLV.

[5] Jour. Geol., Vol. II, 1894, p. 588.

[6] Am. Geologist, April, 1901, Vol. XXVII, p. 225.

[7] The Silurian of the Sierra Nevada in the Taylorville region has not yet been discovered in the Klamath Mountains. (Bull. Geol. Soc. America, Vol. III, p. 376.)

Mr. Hershey submitted some fossils from Pattersons, on New River, which Dr. Girty regards as belonging to the Carboniferous on account of their relation to other and more characteristic fossils found in the Hay Fork region. They are in line with a portion of considerable collections made for the writer last spring in Trinity County by Mr. James Storrs. A belt of lenticular limestone masses having the same general northwest-southeast strike is well exposed a few miles east of Hay Fork, and has been traced for many miles, stretching more or less continuously from near Knob post-office to Pattersons. Fossils were collected at five points along this line, and concerning them Dr. Girty remarks that "the fauna is characterized by the presence of *Fusulina* and strongly indicates the geological horizon to be Upper Carboniferous. Besides a number of corals, there is a pentagonal crinoid stem suggestive of *Pentacrinus*, and a small organism, probably an alga, which occurs in nearly all the localities and is very abundant a few miles southeast of the village of Hay Fork."

Another belt of limestone, the exposures of which are more or less interrupted, has been traced by Mr. Storrs from North Yallo Bally to Hyampom along the eastern slope of the South Fork of Trinity River in Humboldt County. These have yielded fossils at a number of points, among which corals, *Pentacrinus ?*, an echinoid, and two gasteropods have been recognized, but not identified specifically, by Dr. Stanton, who refers them, apparently with some doubt, to the Juratrias.

In the region of Shasta County, extending north and northeast from French Gulch, as far at least as Slatonis, there is a great development of dark slates in which occur local conglomerates. Mr. Storrs collected a large number of fossils, and most of them were obtained from small masses of limestone in the conglomerates. These were referred to Mr. Charles Schuchert, of the National Museum, who reports as follows:

Localities Nos. 5971 [between Tower House and French Gulch], 4, 7, 10, 11, 13, 15, 29, 30, and 31 [on Sacramento River, between Morley and Portuguese Flat] represent one conglomerate horizon. It contains limestone pebbles, sometimes of considerable size, and these were derived from a Middle Devonian formation, apparently the same as that near Kennett, Shasta County. The common forms are *Fistulipora*, *Cladopora*, *Favosites* (two or more species, one of which is *F. canadensis*), *Cyathophyllum*, and *Syringopora*. All of these species are also known in the Middle Devonian limestone near Kennett.

These fossils, however, do not indicate the age of this conglomerate, more than that it is not older than Middle Devonian time. It was deposited subsequent to the Kennett limestone, and there are no fossils either in the pebbles or in the paste (there are some free fossils in the paste, but these are fragments of the same species as those in the pebbles), younger than those mentioned above to more definitely fix the age of this conglomerate.

Locality No. 2 [on Sacramento River, one-third mile above Morley] is a shaly limestone in place. This bed is not represented in our former collections from the Shasta County Devonian. It abounds in *Atrypa missouriensis* Miller (one of

the finely striated forms of *A. reticularis*), *Schizophoria striatula* (Schlotheim), *Cladopora* sp. undet., *Fistulipora* (the same species as the one in the conglomerate), and crinoid stems.

These fossils also indicate Middle Devonian age. At first I supposed that the *Schizophoria* would prove the horizon to be Upper Devonian, but the presence of *A. missouriensis* and *Cladopora* do not support this view. On the other hand, *S. striatula* abounds in both the Middle and Upper Devonian, and our dependence for age determination must therefore rest upon the other fossils.

That the associated slates and conglomerates with fossil fragments are younger than the Middle Devonian is suggested also by some plant remains collected by Mr. Storrs a few miles northwest of Slatonis. Among these Prof. William M. Fontaine recognizes, with some doubt, *Brachyphyllum*, and he remarks "that Brachyphyllum is most developed in the Jurassic and lowest Cretaceous. If we may regard this plant as belonging to that genus, then, so far as its evidence goes, the strata are Jurassic or lowest Cretaceous. But as the generic place of the fossil can not be determined decidedly, and the amount of material is so small, the age can not be certainly fixed. A Jurassic age is indicated." The evidence thus far tends to confirm Mr. Hershey's views[1] as to the age of the Bragdon slates.

In September, 1900, a number of Cretaceous fossils which Dr. Stanton regards as of Horsetown age were found in the valley of the Upper Illinois River near Waldo and Kerby, Oreg. Owing to the presence of this isolated area of soft Cretaceous sediments, a broad valley has been developed at this point. To the northwest the valley sediments are limited by a great mass of peridotite, and in the opposite direction they are cut off by the older rocks of the Siskiyou Mountains. Similar isolated areas of closely allied Cretaceous beds basined in older rocks are well known[2] along Graves Creek in Oregon, and Redding Creek in California.

West of each of the Horsetown localities mentioned *Aucella*-bearing rocks have been found, along Van Deusen River above Hydesville, and along the stage road at Shelly Creek, Cal., 20 miles southwest of Waldo, Oreg. Near the coast in Oregon there is a great thickness of *Aucella*-bearing rocks separating the Chico and Horsetown beds from those of pre-Cretaceous age.

As to the rocks of that portion of the Coast Range which lies southwest of Mad River, a Cretaceous form of *Aucella* (determined by Dr. Stanton) was found along Van Deusen River above Hydesville, and it is certain that some of the sandstones and shales are younger than the rocks which form the mass of the Klamath Mountains. Imperfect fossils were found in the limestone near Laytonville. Among them Dr. Girty reports "a large but indeterminable gasteropod, and a number of small organic bodies which appear to belong to the genus *Mitch-*

[1] Am. Geologist, April, 1901, Vol. XXVII, p. 238.
[2] Fourteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1894, Pl. XLV.

eldeania. This genus has not heretofore been recognized in this country, but the name was given to similar obscure organisms from the Carboniferous rocks of Great Britain. As the form in hand is so similar to the British species (*M. gregaria*) as to be probably identical with it, it seems more than likely that the California rocks are of the same general age." The Laytonville limestone contains small beds of red chert which, under the microscope, is seen to be full of minute, simple, round organisms like those of the radiolarian chert. The limestone, on the other hand, contains a multitude of forms which suggest the foraminiferæ of chalk. The rock is locally gray, but generally reddish, and possibly corresponds to the Foraminiferal limestone described by Prof. A. C. Lawson in his sketch of the Geology of the San Francisco Peninsula.[1]

[1] Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 419.

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PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Bulletin No. 196.]

The publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

The Bulletins (which were formerly sold, but a joint resolution approved May 16, 1902, directed that they should be distributed gratuitously) treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous. This bulletin is the thirty-first in Series F, the complete list of which follows:

BULLETINS, SERIES F, GEOGRAPHY.

5. Dictionary of altitudes in United States, by Henry Gannett. 1884. 325 pp.
6. Elevations in Dominion of Canada, by J. W. Spencer. 1884. 43 pp.
13. Boundaries of United States and of the several States and Territories, with historical sketch of territorial changes, by Henry Gannett. 1885. 135 pp. (Exhausted.)
48. On form and position of sea level, by R. S. Woodward. 1888. 88 pp.
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117. Geographic dictionary of Connecticut, by Henry Gannett. 1894. 67 pp.
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192. Gazetteer of Cuba, by Henry Gannett. 1902. 113 pp., 8 pls.
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196. Topographic development of the Klamath Mountains, by J. S. Diller. 1902. 69 pp., 13 pls.

Correspondence should be addressed to

The DIRECTOR,

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1902

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE

BEREA GRIT OIL SAND

IN THE

CADIZ QUADRANGLE, OHIO

BY

W. T. GRISWOLD

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

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LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Washington, D. C. June 7, 1902.

Sir: I have the honor to transmit herewith the manuscript of a paper on the Berea grit oil sand in the Cadiz quadrangle, Ohio, by W. T. Griswold, with recommendation that it be published as a Bulletin, in the economic series.

I believe that this paper marks a distinct advance in the methods of studying oil fields and of determining and delineating the structure of the oil-bearing formations. While it affords an exceptionally favorable opportunity for subjecting the anticlinal theory of oil and gas accumulation to a rigid test, its primary object is to furnish practical information to the well driller. If the data contained in the paper are properly used in the field, a saving in expense of development will be effected amounting to many times the cost of the work done by the Survey.

Very respectfully,

C. Willard Hayes,
Geologist in Charge of Geology.

Hon. Charles D. Walcott,
Director United States Geological Survey.

THE BEREA GRIT OIL SAND IN THE CADIZ QUADRANGLE, OHIO.

By W. T. Griswold.

INTRODUCTION.

The anticlinal theory of the accumulation of oil and gas is now generally accepted. Through the investigations of Edward Orton, I. C. White, and other geologists working in the great Appalachian oil field, it has been placed on a substantial basis, and has been subjected to the supreme test of prediction. Important practical developments, both in the extension of known fields and in the discovery of new productive territory, have followed its application. In a large part of the Appalachian oil field, however, the geologic structure makes it extremely difficult to determine the localities where oil and gas should accumulate in accordance with the theory. To an extent not generally realized the flexures of the strata are irregular and discontinuous, and the development of one oil pool affords little, if any, assistance in locating others on the same or adjacent anticlines. In a region characterized by such irregular structures, only instrumental work of a high degree of refinement will serve to locate the axes of the flexures and the exact form of their slopes. The first essential in such work is an accurate topographic base map, such as has not been in existence for any part of this field until very recently.

In connection with the topographic mapping of the Cadiz quadrangle, in eastern Ohio, an exceptionally favorable opportunity was afforded for working out the details of structure and subjecting the anticlinal theory to a rigid test. The quadrangle contains several oil pools of considerable productiveness, and there is reason to believe that there are others equally valuable, but as yet undiscovered. The location of prospect wells has hitherto been determined largely by guesswork, and this is an extremely expensive method. The main object of the present report is, therefore, to afford some practical guidance to the driller in locating such prospect wells. As will be pointed out more fully later, correct location with reference to the flexures of the strata is only one of several conditions essential for a productive oil or gas

well. The other factors are porosity of the reservoir rock and degree of water saturation, and their importance has not been sufficiently recognized heretofore. While these can be absolutely determined only by the expensive method of drilling, an exact solution can not be reached until they are determined. A careful study of all existing data derived from wells already drilled in the region will throw light upon the structure and will enable some forecast to be made concerning the probable condition of the oil sand in a given locality where no drilling has been done. It is fully realized that all predictions in regard to oil and gas are of uncertain value, but it is believed that those here made are conservative, and that they will at least prevent much useless expenditure.

PETROLEUM.

Character and origin.—There has been much discussion, and different theories have been advanced, concerning the genesis of petroleum. A review of these discussions would occupy much space; it is sufficient to make a simple statement of those conclusions which have been reached from the consideration of established facts and which are accepted by a majority of the leading geologists.

Petroleum is a complex mixture of hydrocarbons, belonging chiefly to the paraffin series, which are designated under the general formula, C_nH_{2n+2}. It varies in color from pale straw yellow through reddish and dark brown to black. The specific gravity or density varies from 0.777 to 0.907, or from 50° to 16° of the Baumé scale. It is probably derived from organic matter, both animal and vegetable, contained in the shales and limestones of the Silurian and later ages.

Oil in Pennsylvania.—With the discovery of oil in western Pennsylvania, on Oil Creek, a new industry opened. The earlier developments were confined to the lower lands along the streams, and for some time the higher or hill land was not considered available as oil territory. In a short time it was found that the elevation of the surface of the ground had little or no relation to the oil supplies beneath. It was noticed, however, that the productive territory followed lines running in a northeasterly and southwesterly direction, with a bearing of about 45° from true nortn. This gave rise to the 45°-line theory, and a great deal of prospecting was done by extending exploration from a developed pool on a bearing of 45° to the northeast or southwest. As development proceeded toward the south the bearing lines of productive territory gradually changed until, instead of a 45° line, a bearing of 22° from true north or south seemed to lead to the most profitable extensions.

With the development of the natural-gas industry, Mr. W. A. Earsman and other operators noticed that the most productive wells were

located upon or near the lines of anticlinal arches. This important deduction has been expounded and developed by Prof. I. C. White, of Morgantown, W. Va., who has published his conclusions, and has successfully located both gas and oil wells by means of the so-called anticlinal theory.

Relation of oil pools to geologic structure.—Petroleum, being of less specific gravity than the saline waters found in the porous strata beneath the surface, is undoubtedly affected by the slope of the rocks in which it is contained, and tends to collect along lines of nearly equal elevation which parallel the folds of the strata. With this fact in mind, it becomes very easy to account for the 45° and 22° lines which occupied so prominent a place in the early development of the Pennsylvania field. The Appalachian oil field occupies the western flanks of the Appalachian Mountains, the axes of its minor folds having a general parallelism with the folds of that mountain system. Where oil was first discovered these folds have a nearly northeast-southwest direction, but in extending southwest their divergence from true north and south became less, as does that of the major folds of the mountains themselves.

In looking over maps of the oil and gas producing territory, notably those published by the geological surveys of Pennsylvania and West Virginia, and comparing them with maps showing the geologic structure, the gas and oil producing belts and folds are seen to have the same general direction. But there are some notable exceptions to this general statement, if the published information as to the direction of the structure axes is correct. The mapping of the structural lines, however, has been but meagerly and imperfectly done. The minor anticlinal arches have been represented as extending for long distances in straight parallel lines. More detailed work will probably show that their axes are not straight and parallel, but meander with more or less irregularity. This is indicated by the recent work of Marius R. Campbell in Armstrong and Butler counties, Pennsylvania, where the Bradys Bend anticline, instead of continuing in a northeast-southwest direction, makes a sharp bend due west and passes out of Armstrong into Butler County.[a]

It may be assumed in general, therefore, that the minor anticlines do not have anything like the regularity shown on most of the maps now published. They are probably curved and irregular, even much more so than are the larger folds which occur in the mountainous belt to the east. Hence, it would be unsafe to consider any seeming discrepancy between the lines of oil development and the axes of the anticlinal arches as now published as evidence against a theory until very careful geologic work has been done to actually locate the folds.

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[a] Eng. and Min. Jour., February 15, 1902.

Mode of accumulation of oil and gas.—The slope or dip of the oil-bearing formations can have an influence on the accumulation of oil and gas only through the differences in specific gravity between these two substances and the water and air with which they come in contact. Gravity, acting in the manner to be explained below, is the force that has caused the segregation and collection of oil and gas in economic quantities.

The thick shales which constitute an important part of the sedimentary rocks of the oil and gas territory are probably to be looked upon as the source of the oil and gas. These two hydrocarbons, forming in very small quantities over a large territory, have been forced out of the shale into an adjacent porous stratum whenever such porous formation lies in juxtaposition to the oil-bearing shale. These porous strata are saturated with water, and from the nature of their formation must have been so at the time of their original deposition. The porous strata usually consist of sandstone, but in some cases they are composed of limestones which have been under conditions of crystallization that give the rock an open structure.

Assuming a bubble of gas and a drop of oil to have been forced from the underlying shale into a porous sandstone already saturated with water, the natural course of the two particles, owing to their lesser specific gravity, will be to force their way up through the sand rock until a roof or impervious stratum is reached, and here to remain if the cap or cover to the porous stratum is perfectly level. If, however, the cap rock has a slope, there will be a tendency for the hydrocarbons to creep along, always up the slope of the stratum, until a reverse or counter dip is met, at which point an accumulation will be formed, the gas occupying the highest points, with the oil directly beneath it and resting upon the water.

In assuming the existence of a continuously porous stratum entirely filled by water, we are not entirely supported by fact. The sand rocks are of all degrees of porosity, a single bed frequently varying from a coarse conglomerate, with good-sized pebbles having large spaces between them through which any fluid may flow with but little friction, to the finest grained sandstones, through which the passage of a liquid is slow and difficult. At other points the sand grains may be cemented together by lime, iron oxide, or silica into sandstones that are practically impervious to fluids. These differences in the reservoir strata may at any time cause results entirely at variance with the conditions to be expected from the anticlinal theory.

Although these sedimentary beds must have been completely saturated with water when first deposited, they are not always so at present. Some porous beds are freely saturated through their whole extent; others are saturated only in the lower portions of the folds, while the portions which occupy anticlines are almost entirely free

from water. This condition of complete or partial saturation of the porous rocks becomes of the greatest importance in the application of the anticlinal theory to the accumulation of oil. The natural gas, by reason of its less specific gravity than water, oil, or air, will continue to rise in a porous rock until stopped by an impervious cover. The oil, on the other hand, can continue upward only so long as it has the water upon which to climb, and must, therefore, stop at the water line, although this may be but part way up a decided slope. The accompanying sketch, representing an imaginary section through folded strata of petroleum-bearing shale and a porous sandstone capped with an impervious limestone, shows the theoretical method of accumulation of the hydrocarbons.

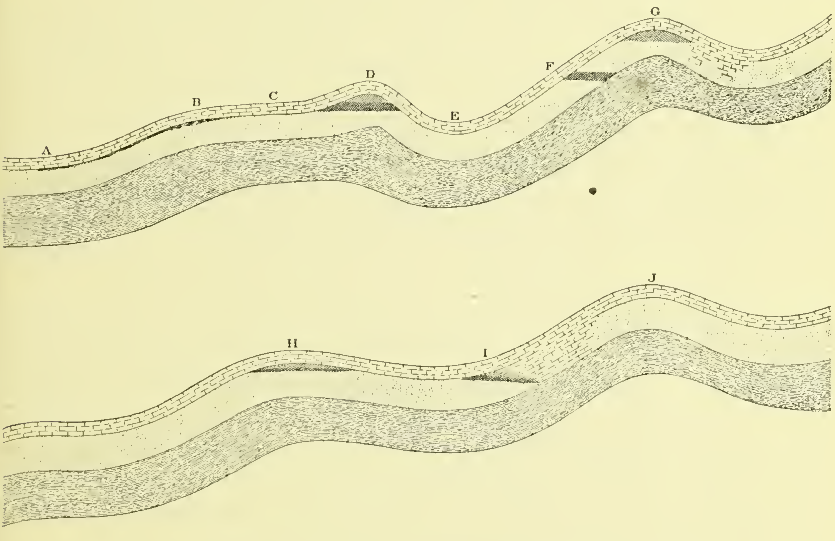


FIG. 1.—Ideal section showing method of accumulation of oil and gas.

The oil and gas, entering the sand rock all along its base, work their way to the roof A, and gradually creep along to the right to the bend or crest of the terrace at B, where the strata become so nearly level that the horizontal tendency of the oil particles is not sufficient to overcome the friction through the sand, while the gas, having more buoyancy, and therefore more force of lateral motion, moves on, leaving the accumulation of oil, unaccompanied by much gas, at the break represented at B. The hydrocarbons entering between C and E gradually work upward until a dome, or anticline, is reached at D, which completely captures both gas and oil. From E to G the tendency is to work toward G, but the higher portion of the sand rock is not completely saturated with water, and the oil can move only to the

upper surface of the water, while the gas passes on to the highest attainable point, leaving what may be a considerable distance between the accumulations of gas and oil.

In the second sketch the same forces have acted, forming an accumulation at H. At I the sand rock has become impervious, and an obstruction is formed that nullifies all calculations from the geologic structure, for it is evident that the oil and gas accumulations will take place at the bottom of the barrier opposed to its movement, though it be near the bottom of a decided slope.

The factors in the problem.—It is evident, therefore, that three important unknown factors affect the accumulation of oil, in addition to the fundamental conditions of a petroleum-yielding shale in juxtaposition to a porous stratum suitably capped with an impervious layer.

First and most important is the internal condition of the sand, which must be such as to allow the passage of the fluid between its particles. Second is the amount of water in the porous stratum, a knowledge of which is necessary for determining at what point with reference to the structure the accumulation of oil may be expected. Third is the geologic structure, or the slopes of the porous stratum. If the strata have a gradual and regular slope over a considerable area, the probabilities are that there have been no accumulations of oil of economic value, but that the supply which has entered the porous stratum is evenly distributed along its upper surface.

The first two factors, relating to the porosity of the rock and the degree of saturation, can be determined only by the expensive method of the drill. The third, however, in certain localities may be to a great extent elucidated by careful geologic work. It is evident that if the cap of the oil-bearing formation formed the present land surface, so that its slopes with its high and low points could be seen, the most probable locations for the collection of oil and gas could be readily selected. This condition is represented in the accompanying map of the Cadiz quadrangle. The surface drainage and the culture, with the Government land-survey lines, are represented as a base, upon which are shown, by means of 10-foot contours in red, the position, slopes, and grades of the top of the cap of the Berea grit oil sand. The present land surface with its hills and valleys is entirely disregarded, and the surface represented by the contours is that which the region would have if all the rocks above the Berea grit were completely removed.

THE CADIZ QUADRANGLE OIL FIELDS.

Location and topography.—The Cadiz quadrangle, Ohio, is bounded by parallels 40° 15′ and 40° 30′, and by meridians 80° 45′ and 81° 00′. It includes parts of Jefferson, Harrison, and Carroll counties, Cadiz being the principal town. Near the western side of the quadrangle is a

north-south ridge which divides the waters flowing directly into the Ohio River from those flowing west and south and finally entering the Ohio at Marietta. The streams have cut their channels into the easily eroded formations to a depth of nearly 300 feet, leaving a confused mass of hills and valleys, with very little or no level land. The hill slopes are seldom too steep for farming, and the country is in a high state of cultivation. The many beds of limestone disintegrate readily, forming arable land of excellent quality.

Areal geology and stratigraphy.—The geologic section exposed by the stream erosion includes about 150 feet of the Upper Productive Coal Measures (Monongahela) and 300 to 400 feet of the Lower Barren Measures (Conemaugh). The Pittsburg coal (No. 8), the bottom of which is the dividing line between these two formations, outcrops near the bottom of the deepest valleys in the southeast corner of the quadrangle. Here is obtained a section above the Pittsburg coal nearly 300 feet in thickness. Toward the northwest the Pittsburg coal rises until, at a point a few miles south of the northern border of the quadrangle, it is found only upon the summits of the highest ridges. Here is obtained a section below the Pittsburg bed fully 300 feet in thickness. In this vertical distance of 600 or 700 feet are found a number of strata that can be easily recognized whenever seen in outcrop, and may be used as guide horizons in determining the geologic structure.

The upper surface of the workable coal in the Pittsburg bed is taken as the datum plane from which the vertical distance, above or below, is calculated to other horizons, in all cases the top of the stratum mentioned being taken.

The Pittsburg bed has a thickness of about 4½ feet of workable coal, and above this is a thin bed of fire clay, followed by 1½ feet of impure coal, or coal blossom.

In ascending order from the Pittsburg bed the following easily recognizable strata are found: (1) a hard, dark-blue limestone, lying but a few feet above the Pittsburg coal, and called "Upper 8 limestone;" (2) a thin bed of coal, rarely over 6 inches, occurring in the shale and known as the "Pittsburg rider vein;" (3) a coal bed with a thickness of from 8 to 16 inches, known as "Meigs Creek coal;" (4) an 8-inch bed of cream-white limestone, intersected by thin seams of crystallized calcite, here referred to as "Meigs Creek white limestone."

Below the Pittsburg coal are found (1) a bed of limestone very similar to that above, here called "Lower Pittsburg lime;" (2) a bed of coal less than 1 foot in thickness, and called "No. 7 b;" (3) the Ames limestone, from 2 to 4 feet in thickness, of a greenish color, and carrying a great number of crinoidal stems; (4) the Ames coal, often found directly beneath the Ames limestone; (5) a bed of coal from 1 to 3 feet in thickness, called "No. 7 a."

In selecting the measurements for determining the vertical distance between these different strata, only those were used which were obtained where the formations were known to be lying nearly level, or where the horizontal distance between the two outcrops was small. In cases where two outcrops of the same bed could be obtained and the outcrop of another stratum was found approximately halfway horizontally between the two, an average of the elevations of the two outcrops of the one bed above the other was used in order to eliminate the error from dip of the strata.

The most useful beds for plotting the geologic structure have been the Meigs Creek coal, the Pittsburg coal, and the Ames limestone. The other strata have not always been found in their expected positions, and the number of good comparisons between them and the Pittsburg coal have been fewer, so that their true position is not considered so well established.

The following tables give the determined vertical distance between the top of the workable coal of the Pittsburg bed and the top of the various coals and limestones mentioned above:

Vertical distance from Pittsburg coal to top of Meigs Creek white lime.

	Feet.
Church at Bloomfield	132
One and a half miles south of Smithfield	119
On Smithfield and Cadiz road near Piney Fork	113
On Cadiz and York road near Hurford Creek	111

Vertical distance from Pittsburg coal to top of Meigs Creek coal.

At the town of Bloomfield	99
On hill between two McIntyre creeks, north of Smithfield	92
One and a half miles southwest of Smithfield	94
On Smithfield and Cadiz road near Piney Fork	97
On Cadiz and York road near Hurford Creek	94
On farm road near north line of township 10, range 4	93

Vertical distance from Pittsburg coal to top of Pittsburg rider vein.

On Cadiz and York road near Hurford Creek	26
On Cadiz and Unionvale pike near Cadiz	24
On road near north line of township 10, range 4	21
On ridge east of Amsterdam	26

Vertical distance from Pittsburg coal to Upper No. 8 limestone.

On Cadiz and Unionvale pike near Cadiz	12
On ridge east of Amsterdam	19

Vertical distance from Pittsburg coal to Lower No. 8 limestone.

On Cadiz and Unionvale pike near Cadiz	7
On ridge east of Amsterdam, west summit	11
On ridge east of Amsterdam, east summit	9

Vertical distance from Pittsburg coal to coal No. 7 b.

	Feet.
On Cadiz and Unionvale pike near Cadiz	134
On Cadiz and Hopedale road near Greenough	127

Vertical distance from Pittsburg coal to top of Ames limestone.

From ridge south of Opossum Hollow into Opossum Hollow	218
From ridge north of Opossum Hollow to Skelley road	213
On road from Bloomfield to Bloomfield station	221
On ridge south of Amsterdam	220
On road from East Springfield to Shane post-office, via Town Fork	217
Near Carmen station	205
Near Richmond	230

METHOD OF CONSTRUCTING THE CONTOUR MAP OF THE OIL SAND.

From the permanent bench marks established, spirit-level lines were run over nearly every road and up a great many hollows, establishing the true elevation of about five hundred outcrops of recognizable geologic horizons. By then adding to or subtracting from each elevation thus determined an amount equal to the vertical distance between the particular bed located and the Pittsburg coal, the elevation of the Pittsburg coal at these points was obtained. These points were then plotted and there was thus prepared a map having marked upon it the elevation of the key horizon, the Pittsburg coal, at 500 points. By connecting the points of equal elevation, a contour map showing the folds of this key horizon was made, the accuracy of this map depending upon the number of elevations obtained and their even distribution over the quadrangle.

The vertical distance from the Pittsburg coal to the Berea grit at each test well was obtained by comparing the elevation of the mouth of the well with the elevation of the Pittsburg coal at that point and adding this difference of elevation to, or subtracting it from, the distance from the mouth of the well to the Berea grit as given by the well record. This distance from the Pittsburg coal to the Berea grit was found to vary, but with a quite remarkable regularity. The true position of each test well was then plotted and the vertical distance between the Pittsburg coal and the Berea grit marked upon the map. The positions of the different test wells were connected by straight lines and these lines were divided so that each subdivision represented the horizontal distance in which the vertical distance from the Pittsburg coal to the Berea grit decreased 5 feet. The points of equidistance from coal to sand were then connected and a drawing was built up called the convergence sheet. This shows by a series of lines the points of equal distance between the Pittsburg coal and the Berea grit.

The convergence sheet was then placed over the plot showing elevations of the key horizon, and it showed at once the amount that should

be subtracted from the elevation of the Pittsburg coal to determine the elevation of the Berea sand at any point. The elevation of the Berea sand at every point where it was determined was then marked on the map and the points of equal elevation were again connected, resulting in a contour map of the oil-bearing sand (Pl. I).[a] The map was drawn in 10-foot contours, as this seems the most desirable interval for the use of the oil operator, though it is hardly to be expected that the drill will always find this degree of accuracy in the work.

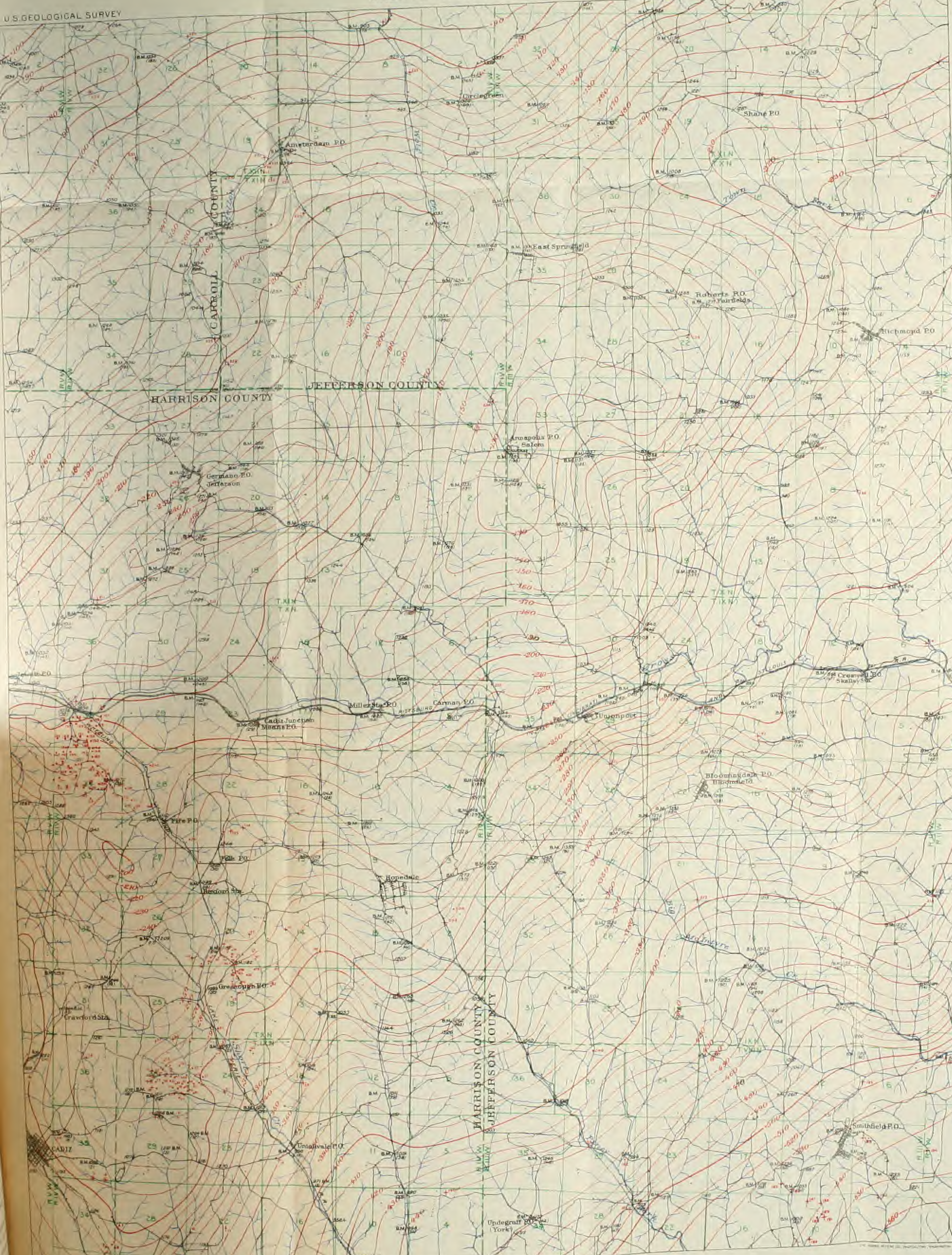
In making such a map in the manner above outlined it is evident that there are several sources of error which can not be entirely provided against. Thus, a bend or change of dip may occur at a point at which there is no outcrop of any one of the guide horizons. The difference of elevation having been determined at two points, the slope of the oil sand between them is represented as uniform, while, in fact, it may be horizontal for a part of the distance and have a steep dip for the remainder. The records of test wells, although carefully taken at the time of the drilling, can sometimes be procured only from the memory of the driller, and the only check upon their correctness is from the resulting appearance of the divergence sheet. Again, a sudden change in the rate of divergence between the key horizon and the oil sand may occur where no test well has been drilled, in which case the divergence sheet will show an erroneous uniformity. All of these conditions probably do happen, making the map more generalized than the contour interval would indicate.

The true elevation of the top of the sand, although very desirable to know, is not absolutely necessary to the usefulness of the map. If there is an error of 20 to 30 feet in the elevation of the sand—the probable maximum error—there will be the same or nearly the same error in the elevation of adjacent portions of the bed, and the relative dip or slope between the two places will be approximately as represented upon the map. Since this is the really important feature of the map, the errors in absolute elevation, due to the causes above enumerated, are less serious than they might at first sight appear.

RELATION OF PRODUCTIVE TERRITORY TO STRUCTURE IN THE CADIZ QUADRANGLE.

Description of the structure.—The accompanying contour map of the Berea oil sand shows a system of parallel folds, forming elongated domes and canoe-shaped basins, with an indication of cross folding about at right angles to the principal system. The most prominent feature is the main anticlinal arch, which extends from near the southwest corner of the quadrangle in a northeasterly direction, passing just east of the town of Salem, where it attains its greatest height.

[a] As the key horizon map and the convergence sheet represent merely steps in the process of making the map of the oil sand, it is not deemed necessary to publish them.



Topographic base from surveys of the U.S. Geological Survey, Chas. D. Walcott, Director, in cooperation with the State of Ohio, G.K. Nash, Governor

CONTOUR MAP OF THE BEREA GRIT OIL SAND

By W. T. Griswold

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Thence it swings to a more easterly direction and rapidly falls away before reaching Richmond. The corresponding syncline parallels this fold on the western side, but is interrupted by two cross anticlines, one near the line of the Pittsburg, Cincinnati, Chicago and St. Louis Railroad, the other very nearly agreeing with the location of the ridge road from East Springfield north toward Bergholtz. It thus forms a canoe-shaped basin whose lowest point is but a short distance east of the town of Jefferson, and part of another basin which extends almost due east and west, its center line being very near the location of the middle ridge. To the east of the main anticline the sand descends in terraces or steps to the eastern limit of the quadrangle, the crests of the terraces extending in lines parallel to the main anticlinal folds. Over this slope the intersection of the cross folds has the effect of obliterating the terrace for some distance and throwing its steep slope farther toward the east after passing the secondary fold.

No long and steep slopes exist in the quadrangle. The slope is steepest on the face of the terraces, where it seldom amounts to 100 feet to the mile. This lack of decided slope for a considerable distance is unfavorable to the probable accumulation of a large pool of oil, since no large area of oil-producing territory has been drained into a single continuous reservoir.

Smithfield pool.—The southern half of the quadrangle has been very generally prospected for oil. In the southeast corner, near the town of Smithfield, two producing wells (Nos. 189 and 190) have been found on the farm of Mr. Charles Galbraith. These two producers have been nearly encircled by test wells in hopes of extending this pool, but with unfavorable results. The two producing wells seem to be upon a nearly level terrace and in what appears to be a most unlikely place for the accumulation of oil, from the indication of the contour map. To the southeast of the producing wells only one coal outcrop was leveled to. Well No. 193 found the sand 20 feet lower than would be expected from this outcrop. It is possible, therefore, that the sand descends faster in the southeast corner than is represented on the map. From this it would seem that the most favorable direction for prospecting is to the southeast of the producing wells.

Bloomfield anticline.—Passing north from Smithfield over the McIntyre creeks the sand is found to rise rapidly, until it culminates in a nose jutting out at right angles to the direction of general folding, with its highest point in sec. 10, and extending southeasterly to east of the colored settlement near McIntyre Creek. This would seem to indicate a favorable point for oil accumulation, and it is probable that if good sand be found on the sides of this secondary anticline it will be saturated with oil, the most probable location being in a northeasterly line through sec. 2, T. 9 N., R. 3, and secs. 32 and 33, T. 6 N., R. 2, with a favorable chance for small wells on the west

side of the fold in secs. 2 and 8, T. 9, R. 3. Four test wells have been drilled that may be considered as having a bearing upon this possible oil territory. Well No. 195, on the farm of William Cope, is rumored, though no positive information was obtained, to have found very poor or no sand. Well No. 217, on the farm of J. Dodds, found very poor sand, with but little water and slight show of oil. Well No. 218, on Joshua Moore's farm, found the Berea grit to consist from top to bottom of lime formation, incapable of holding any large amount of fluid. Well No. 196, at Southerland's mill, found very good sand, with indications of oil. After shooting this well a number of barrels of oil were bailed out. Wells Nos. 195 and 217 from their locations could not have been expected to be large producers, but had they made a show of salt water would have very much improved the chance of good producing territory on the anticline. Well No. 196 seems to have made a better show than was to be expected, and is apt to suggest the idea that the impervious sand extends for a considerable distance down the side of the anticline. Well No. 218 proves nothing except that poor sand exists at the point where the well was drilled. With the evidence of these wells taken into consideration, this area must be regarded as having favorable structure, but with strong probabilities of finding poor sand.

Salem area.—On the eastern side of the main anticline, north of the secondary fold above mentioned, no noticeable features are shown, and a selection of the most favorable territory would be very hard to make, though a test well in the south part of sec. 20 or 26 would have a fair show of success, and if a failure, would furnish valuable data as to the probability of an oil pool in that locality.

Piney Fork test wells.—To the west of Smithfield, on and near the Piney Fork of Short Creek, four test wells have been drilled. Well No. 182, on the farm of Alexander S. Thompson, gave a fair show of oil. This well is shown by the map to be at the crest of a small terrace. The other wells, Nos. 181, 183, and 240, were simply dry holes.

Bricker pool.—From this locality westward no favorable territory is shown until reaching the producing area on the main anticline northeast of the town of Cadiz. Here the Bricker pool was opened up in sec. 30 by well No. 49, which started at 150 barrels. The sand at this pool is very favorable, and it has furnished a number of wells that started at over 100 barrels per day. This pool is not giving evidence of long life. The productive territory has been definitely limited by four gas wells on the west, three dry holes on the north, also three dry holes on the south, with a strong salt-water well, No. 57, on the east.

Southern extension of main anticline.—Beyond the three dry holes on the Rife farm, the southern extension of the eastern slope of the

anticline has been tested only by well No. 13, on the Porter farm. This well found 8 feet of good sand, with good show of oil and large amounts of salt water. The map represents this well as located too far down the slope of the anticline. Its results, however, give evidence for the probability of producing territory in the northeast quarter of sec. 28 and the southeast quarter of sec. 29.

The area west of the anticline may all be considered as favorable territory for small wells. Although not shown on the map, it is known that a strong syncline parallels the line of the anticline just off the western edge of the quadrangle, and encounters the cross anticline at the Jewett oil field, which field covers a considerable area with small-producing wells.

Snyder pool.—On the eastern side of the main anticline, 2 miles northeast of the Bricker pool, what is known as the Snyder field has been developed during the last year. The sand here is not so favorable as at the Bricker pool, but a number of 30- and 40-barrel wells have been found.

Northern extension of the main anticline.—North and northeast of the Snyder pool six wells have been sunk in the attempt to find other pools by an extension of the alignment of the Bricker and Snyder pools, with uniformly unfavorable results. With the information shown by the contour map, these results would not have been unexpected. It is here that the influence of the cross anticline has come in, and the terrace face has been moved over to the east of the town of Hopedale, where it again takes up its northeasterly direction, and is in fact the extension of the Bricker and Snyder pool terrace. Two test wells have been drilled at the southeast end of this terrace. The first well, No. 203, found sand, with a show of oil, and led to the drilling of the second well, No. 204, with the intention of striking the sand fully 10 feet higher than in the first well. This they failed to do, finding the sand only 2 feet higher in the second well than in the first. This slightly increased elevation showed very favorably in the oil indications, and the well was put to pumping, resulting in from 1½ to 2 barrels a day.

Wells Nos. 205 and 206 were small producers, but not from the Berea grit sand, since they were sunk only to the Cow Run sand. Other wells near Nos. 205 and 206 were drilled to the Berea grit, and were unproductive. Their location and records have not been procured. The result of well No. 202, in sec. 28, was not learned. Well No. 201, in sec. 23, is reported as a gas well.

From the structure and indications of test wells already drilled, a very favorable line for finding oil seems to exist in a northeasterly direction from the southeast quarter of sec. 3, toward the town of Unionport.

Amsterdam pool.—The accumulation from the canoe-shaped basin on the western side of the main anticline has been discovered in part at Amsterdam.

The sand at the Amsterdam wells is of such a poor quality that it probably would have been reported as all lime had it not been oil-producing. The wells are small, but will probably improve when spots of better sand are found. The limits of this field have been determined across the dip of the sand by a salt-water well, No. 205, and a gas well in sec. 19, not located on the map. The lateral extensions along the strike are as yet not defined by test wells. The indications are that the extensions will be to the southwest in a diagonal line through sec. 30, and to the east in an almost due east line through the south half of sec. 7.

USE OF THE STRUCTURE MAP.

To obtain the most valuable result from the use of the map of the oil sand, it is necessary to know the true elevation of the mouth of a contemplated well. For this purpose the elevations of the surface at a great many intersections of roads and other spots have been printed on the map. The letters "B M" have been prefixed to two hundred of these elevations, and beneath each has been placed one of the numbers of the consecutive series appearing in the first column of the bench-mark descriptions on pages 34 to 42. These bench marks have been so distributed that it is hoped any point may be reached by not over 1 mile of leveling.

After obtaining the true elevation of the mouth of the proposed well, add to it the elevation of the oil sand, as shown by the contour map, at the point where the well is to be drilled, disregarding the minus sign. The sum will be equal to the depth of well required to reach the top of the sand, and by increasing this amount by 40 to 60 feet the total depth of well will be found. By subtracting 350 feet from the computed distance from mouth to top of Berea sand, a very close estimate can be made of the casing required to extend through the Big Indian sand.

WELLS AND BENCH MARKS IN CADIZ QUADRANGLE, OHIO.

List of wells in the Cadiz quadrangle.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.*[a]	*Feet.*	*Feet.*	*Feet.*	
1	R. R. Cochran	10	5	6	Cadiz Oil and Gas Co		1,151	1,414	−263	50	1,180	1,443	Dry hole; first well near Cadiz.
2							1,075						Produced a few barrels natural; after shooting no oil.
3	C. M. Hogg	9	4	35				1,431					
4	do	9	4	35			1,063						
5	G. Fryer	9	4	34	Cadiz Oil and Gas Co		1,034	1,345	−311	50	1,185	1,496	Gas well.
6	do	9	4	28	do		1,022	1,317	−295	59	1,185	1,480	Do.
7		9	4	34	do								
8		9	4	34	do		1,144						
9	Jos. Thompson	9	4	34	do	1							
10	do	9	4	34	do	2							
11													
12	Jno. Clifford	9	4	22			1,107						
13	S. B. Porter	9	4	22	Wilson & Pratt	1	1,213	1,572	−359	31	1,145	1,504	Small show. Good sand; some oil, with large quantity of salt water.
14	Geo. Kerr	9	4	17			1,036						
15	J. & J. W. Rife	9	4	29	Ohio Oil Co	1	1,133	1,423	−290		1,192	1,482	Dry hole.
16	do	9	4	29	do	3	1,186	1,477	−291	53	1,194	1,485	Do.
17	do	9	4	29	do	2	1,220	1,498	−278		1,203	1,481	Dry hole. Poor sand; lime extended 35 feet.
18	Samuel Thompson	9	4	30	do	2	1,156	1,440	−284				Gas well.
19	do	9	4	30	do	1	1,177	1,460	−283		1,201	1,484	Do.
20	do	9	4	30	do	4	1,130	1,410	−280				Do.
21	do	9	4	30	do	3	1,196	1,479	−283	26	1,205	1,488	

[a] Minus sign indicates distance below sea level.

List of wells in the Cadiz quadrangle—Continued.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.*[a]	*Feet.*	*Feet.*	*Feet.*	
22	Samuel Robb	9	4	30	Hogg & Glover	5	1,179	1,463	−284				
23	.....do	9	4	30	.....do	7	1,124	1,408	−284		1,203	1,487	
24	.....do	9	4	30	.....do	2	1,159	1,452	−292				
25	.....do	9	4	30	.....do	1	1,072	1,368	−296				140 barrels.
26	.....do	9	4	30	.....do	3	1,114	1,402	−288				
27	.....do	9	4	30	.....do	4	1,135	1,417	−282	33			Strong gas.
28	.....do	9	4	30	.....do	6	1,193						
29	John Bricker	9	4	30	National Oil Co	6	1,135		−285				Records of National Oil Co. do not give top of sand cap; 17 feet was subtracted from record of top of pay sand for elevation of cap rock.
30	.....do	9	4	30	.....do	4	1,120		−303				
31	.....do	9	4	30	.....do	8	1,114		−280				
32	.....do	9	4	30	.....do	9	1,105		−288				
33	.....do	9	4	30	.....do	3	1,097		−289				
34	.....do	9	4	30	.....do		1,037		−308				
35	.....do	9	4	30	.....do	12	1,135						
36	.....do	9	4	30	.....do	10	1,032		−303				
37	.....do	9	4	30	.....do	16	1,156		−290				
38	.....do	9	4	30	.....do	14	1,178		−307				
39	.....do	9	4	30	.....do	13	1,151						
40	.....do	9	4	30	.....do	15	1,205		−294		1,187	1,481	
41	.....do	9	4	30	.....do	20	1,216						
42	.....do	9	4	30	.....do	17	1,214						
43	.....do	9	4	30	.....do	19	1,198		−301				
44	.....do	9	4	30	.....do	18	1,187						

45	Samuel Robb	9	4	30	do	3							
46	do	9	4	30	do	5							
47	do	9	4	30	do	1							
48	do	9	4	30	do	4							
49	John Bricker	9	4	30	do	1	1,037		—291				180 barrels.
50	do	9	4	30	do	11	1,086		—301				
51	Samuel Robb	9	4	30	do	2							
52	John Bricker	9	4	24	do	2	1,069		—294				
53	Jno. Baker	10	4	25			1,096						Dry.
54	Robt. Junk	10	4	25			1,099						Do.
55	Ingram Clark	10	4	25	Ohio Oil Co	1	1,195	1,480	—285				Do.
56	Samuel Robb	9	4	30	National Oil Co	6	1,085		—297				
57	Robt. Busby	9	4	24	do	1	1,023	1,326	—303		1,180	1,483	Salt water.
58	Emmit Thompson	9	4	36			1,150	1,418	—268		1,208	1,476	Dry.
59	J. S. Black	9	4	18			1,011	1,368	—357		1,138	1,495	
60	F. Barricklow	9	4	24									
61	D. Robb	10	4	19	Ohio Oil Co	1	1,029	1,335	—306		1,194	1,500	
62	John B. Thompson	10	4	19			1,062						
63	W. Beadle	10	4	19	National Oil Co	3	1,185	1,493	—308				
64		10	4	19			1,092						
65	P. H. Stephens	10	4	19	Davis & Johnson	2	1,190						
66	do	10	4	19	National Oil Co	1	1,092						
67	do	10	4	19	do								
68	do	10	4	19	do	2	1,123						
69	do	10	4	19	do	4							
70	do	10	4	19	do	3							
71	do	10	4	19	Davis & Johnson	3	1,205						
72	do	10	4	19	do	1	1,225						
73	Jacob Snyder	10	4	20	do	1	1,178	1,470	—292				
74	do	10	4	20	do	4	1,215	1,483	—268				
75	do	10	4	20	do	9	1,162	1,425	—263				
76	do	10	4	20	do	5	1,196	1,455	—259				
77	do	10	4	20	do	2	1,208	1,470	—262		1,211	1,473	
78	do	10	4	20	do	8	1,224	1,480	—257				

a Minus sign indicates distance below sea level.

List of wells in the Cadiz quadrangle—Continued.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.a*	*Feet.*	*Feet.*	*Feet.*	
79	Jno. O. Copeland	10	4	20	Davis & Johnson	1	1,202	1,475	−273				
80	Jacob Snyder	10	4	20	.....do	3	1,163	1,455	−292				
81	Wm. Croskey	10	4	14	.....do								
82	.....do	10	4	13	.....do								
83	F. B. Cole	10	4	20	Amsler & Rowley	3	1,184	1,449	−265		1,211	1,476	
84	Jacob Snyder	10	4	20	Davis & Johnson	7		1,470					
85	F. B. Cole	10	4	20	Amsler & Rowley	2	1,206	1,464	−258		1,213	1,471	
86	.....do	10	4	20	.....do	1	1,230	1,487	−257		1,213	1,470	20 barrels.
87	Jacob Snyder	10	4	20	Davis & Johnson	6	1,212	1,470	−258		1,213	1,471	
88	F. B. Cole	10	4	20	Amsler & Rowley	5	1,218						
89	.....do	10	4	20	.....do								
90	E. Norman	10	4	20	Hogg & Hedges	3							
91	.....do	10	4	20	.....do	1	1,224	1,487	−263		1,213	1,476	Do.
92	.....do	10	4	20	.....do	2	1,125	1,382	−257		1,213	1,470	30 barrels.
93	.....do	10	4	20	.....do		1,078						
94	F. B. Cole	10	4	20	.....do	1	1,075						
95	.....do	10	4	20	.....do	2							
96	.....do	10	4	20	.....do	3	1,126						
97	O. Snyder	10	4	20									
98	S. Laughidge	10	4	20									
99	Jno. M. Copeland	10	4	20	Ohio Oil Co.	1	1,217	1,476	−259				
100	S. B. McGavran	10	4	26	Wallace & Co.								
101							1,157						
102													
103							1,214	1,456	−242		1,233	1,475	
104							1,159						
105							1,123		−251				

106	....	......	......	......	....		1,086	....	....	......	....	....	
107	....	......	......	......	....		1,075	....	....	......	....	....	
108	J. Brindle	10	4	28	F. N. Donalson	2	....	1,352	....	......	....	....	Gas well.
109	.....do	10	4	28	.....do	1	....	1,410	....	......	....	....	
110	Mintur	10	4	28	.....do	1	1,198	1,410	−212	......	....	....	
111	....	10	4	28	....		....	....	....	......	....	....	
112	Maggie Finicum	10	4	34	F. N. Donaldson	1	1,234	1,444	−210	......	....	....	
113	.....do	10	4	34	.....do	2	1,198	1,414	−216	......	....	....	
114	Mintur	10	4	28	.....do	2	....	1,443	....	......	....	....	
115	....	10	4	34	....		....	....	....	......	....	....	
116	Maggie Finicum	10	4	34	F. N. Donaldson	3	....	1,296	....	......	....	....	
117	Joseph McCullough	10	4	34	Ohio Oil Co	1	1,081	1,295	−214	......	....	....	
118	....	10	4	34	....		....	....	....	......	....	....	
119	Joseph McCullough	10	4	34	....		....	....	....	......	....	....	
120	.....do	10	4	34	Ohio Oil Co	3	1,165	1,400	−235	3	....	....	
121	.....do	10	4	34	.....do	2	1,180	1,394	−214	......	....	....	
122	....	10	4	34	....		....	....	....	......	....	....	
123	....	10	4	34	....		....	....	....	......	....	....	
124	....	10	4	34	....		....	....	....	......	....	....	
125	....	10	4	34	....		....	....	....	......	....	....	
126	....	10	4	34	....		....	....	....	......	....	....	
127	....	10	4	34	....		....	....	....	......	....	....	
128	....	10	4	34	....		....	....	....	......	....	....	
129	....	10	4	34	....		....	....	....	......	....	....	
130	....	10	4	34	....		....	....	....	......	....	....	
131	Joseph Thompson	10	4	34	Ohio Oil Co	5	1,275	1,500	−225	......	1,232	1,457	
132	.....do	10	4	34	.....do	6	1,285	1,510	−225	......	....	....	
133	....	10	4	34	....		....	....	....	......	....	....	
134	H. L. Thompson	10	4	34	Ohio Oil Co	6	1,193	1,409	−216	......	....	....	
135	.....do	......	4	34	.....do	5	1,158	1,365	−207	......	....	....	
136	.....do	10	4	34	.....do	4	....	....	....	......	....	....	
137	.....do	10	4	34	.....do	11	....	....	....	......	....	....	
138	.....do	10	4	34	.....do	3	1,124	1,334	−210	......	....	....	
139	.....do	10	4	34	.....do	12	....	....	....	......	....	....	

[a] Minus sign indicates distance below sea level.

List of wells in the Cadiz quadrangle—Continued.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.*[a]	*Feet.*	*Feet.*	*Feet.*	
140	H. S. Thompson	10	4	34	Ohio Oil Co.	1	1,201	1,408	−207				
141													
142													
143													
144													
145													
146	H. L. Thompson	10	4	34	Ohio Oil Co.	10	1,218	1,432	−214				
147	John McCullough	10	4	34	do	1		1,417					
148	do	10	4	34	do	4	1,237	1,448	−211		1,240	1,452	
149	T. M. Lee	10	4	35	do	2	1,212	1,426	−214				
150	do	10	4	35	do	1		1,390					
151	A. M. Busby	10	4	35	do	2	1,162	1,364	−202				
152	do	10	4	35	do	6							
153	do	10	4	35	do	4	1,051						
154	R. D. Lee	10	4	35	do								
155	do	10	4	35	do	3	1,034	1,239	−205				
156	do	10	4	35	do	4	1,033	1,236	−203				
157	do	10	4	35	do	5	1,038						
158													
159	A. M. Busby	10	4	35	Ohio Oil Co.	1	1,096						
160	do	10	4	35	do	3	1,030	1,227	−197	39			
161	Maggie Busby	10	4	35				1,232					
162	S. E. Thompson	10	4	35	E. Thompson Co.	7				36			
163	do	10	4	35	do	6	1,199	1,409	−210	34			
164	do	10	4	35	do	5	1,148	1,354	−206	40			
165	do	10	4	35	do	4	1,125	1,336	−211	40			
166	do	10	4	35	do	1	1,082	1,288	−206	41			

167													
168													
169													
170	A. M. Busby	9	4	35	Jewett Oil Co.	1	1,036	1,240	−204				Gas.
171	....do	9	4	35	....do	2	1,072	1,269	−197				Do.
172													
173													
174													
175													
176													
177													
178													
179													
180	W. Harvey Johnson	9	4	3			1,148	1,588	−440		1,099	1,539	Dry.
181	K. Southerland	8	3	28			979				1,068		
182	A. S. Thompson	8	3	29			991	1,446	−455	55	1,091	1,546	Some oil.
183	W. Vermillion	8	3	29			988						
184													
185	L. Runyon	8	3	17			1,039	1,582	−543		1,026	1,569	Full record.
186	J. and J. Galbreth	8	3	11			1,033						
187	....do	8	3	10	Ohio Oil Co.	2	1,234	1,764	−530		1,025		
188	....do	8	3	10			1,091	1,628	−537		1,024		
189	C. Galbreth	8	3	10	C. Galbreth	1	1,069	1,610	−541		1,023	1,564	
190	....do	8	3	10	....do	3	1,094	1,634	−540		1,023	1,563	
191	....do	8	3	10	....do	2	1,114	1,655	−541		1,023	1,564	
192	W. S. Purviance	8	3	10			1,002	1,551	−549		1,021	1,570	
193	Eliza Lewis	8	3	4			1,073	1,654	−581	47			
194							1,053						
195							985						
196	J. W. Southerland	7	2	36			918	1,432	−514		1,062	1,576	
197	M. Semeral	9	3	17			1,067	1,380	−313		1,197	1,510	
198													
199													
200	W. S. Blackburn	9	3	23			918	1,221	−303	43	1,203	1,506	

a Minus sign indicates distance below sea level.

List of wells in Cadiz quadrangle—Continued.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.a*	*Feet.*	*Feet.*	*Feet.*	
201	T. M. Reed	9	3	23			939	1,199	−260		1,221	1,481	Gas.
202	E. Hervey	9	3	28			1,038	1,344	−306		1,197	1,503	Full record.
203	M. McFadden	9	4	2			1,110	1,390	−280		1.210	1,490	Good sand.
204	C. Hedges	9	4	2			1,152	1,430	−278		1,212	1,490	1½ barrels.
205							998						
206							987						
207	C. Morrigan	10	4	12			1,025	1,182	−157		1,308	1,465	
208	L. B. Rolston	10	4	18			1,071				1,273		
209	Lowmiller	11	4	26			1,152	1,368	−219		1,238	1,457	
210	Jno. Condo	11	4	25			1,118						
211	Geo. Crabb	11	4	31			1,041						
212	L. B. Rolston	10	4	8			1,190				1,238		
213													
214	H. Starr	9	3	18			911	1,191	−280		1,228	1,508	
215		9	4	35			1,108	1,400	−292		1,201	1,493	
216													
217	J. Dodds		3	21	Amsler & Rowley		1,121	1,526	−405		1,122	1,527	Poor sand.
218	J. & L. Palmer		3	3			1,070	1,472	−402		1,150	1,552	Do.
219	Geo. Folhr				Ohio Oil Co.			1,170					
220													
221	W. Andrews	10	3	6			880	1,085	−205		1,250	1,455	
222							1,228						Coal test well.
223							933						
224	A. J. Anderson						898	995	− 97	40			Gas.
225	John Knox	11	4	18			961	1,167	−206		1,277	1,483	Salt water.
226	Wm. Seaton	11	4	24			945						
227	A. Long	12	4	13	W. C. Kennedy & Co.	2	933	1,109	−172				

228	Wm. Seaton	11	4	24	.....do	2	1,070	....	....	....	....	....
229	A. Long	12	4	19	.....do	1	993	1,163	−170	....	....	....
230	.....do	12	4	19	H. N. R. O. I. Co	1	953	1,114	−161	....	....	....
231	.....do	12	4	19	.....do	2	....	....	....	....	....	....
232	.....do	12	4	19	.....do	3	1,040	1,196	−156	....	....	....
233	M. & J. Hess	11	4	24	.....do	1	1,016	1,164	−149	....	1,316	1,465
234	Robt. H. Miser	11	4	3	Wallace & Co	......	1,087	1,268	−181	....	1,333	1,514
235	Soloman Burrier	11	4	28	Carrol & Jeffee Oil Co	......	1,032	1,209	−177	....	1,289	1,466
236	Adam Burrier	11	4	22	.....do	......	1,052	1,257	−205	....	....	....
237	T. A. Stenger	12	4	31	....	......	1,135	....	....	....	....	....
238	R. Gibson	12	4	32	....	......	1,177	1,277	−100	....	....	....

a Minus sign indicates distance below sea level.

List of bench marks in the Cadiz quadrangle.

[Numbers and elevations of permanent bench marks in heavy-faced type.]

No. on map.	Elevation.	Description.
	Feet.	
1	**1,280.10**	Aluminum tablet sunk in west end in first landing of stone step at north entrance to Cadiz court-house.
2	1,056.00	B. M. cut in top of guard wall of stone arch bridge on Cadiz and Unionvale pike, 1 mile east of Cadiz.
3	1,201.00	B. M. painted on floor of coal wharf near brick house on Craig farm.
4	998.05	B. M. painted on top of bridge No. 192 B of Wheeling and Lake Erie R. R.
5	**971.40**	Copper tablet sunk in northwest bridge seat of bridge No. 193 A of Wheeling and Lake Erie R. R., one-half mile south of Unionvale.
6	938.60	B. M. painted on northwest wall of wagon bridge near Jobe Station on Wheeling and Lake Erie R. R.
7	925.60	B. M. cut in top stone of northeast abutment of Wheeling and Lake Erie R. R. bridge at Hurford Station.
8	1,083.40	B. M. painted on south rail of bridge on Cadiz and Bricker road, 1 mile east of Cadiz.
9	1,171.70	Floor of small bridge at intersection of roads near the residence of Samuel Thompson.
10	1,211.70	B. M. painted on bottom rail of fence at forks of roads near Bricker oil field.
11	1,256.30	B. M. painted on fence post at summit by large oak tree on road from Bricker oil field to Craig schoolhouse.
12	1,264.18	B. M. painted on fence rail on west side of road at summit near red house.
13	1,228.65	Top of highest rail of Cadiz Branch R. R. at street crossing at north end of Cadiz.
14	1,222.40	Top of south rail of Cadiz Branch R. R. at Looftsboroughs' crossing.
15	1,263.60	Top of west rail of Cadiz Branch R. R. opposite Crawford station.
16	1,243.70	Top of rail at road crossing over Cadiz Branch, eight-tenths of a mile south of Limestone Station.
17	1,209.10	B. M. top of railroad spike driven in top of post on east side of Cadiz Branch at road crossing one and eight-tenths miles south of Falk Station. Elevation of west rail at road crossing, 1,211.90.
18	1,198.90	Road crossing over Cadiz Branch at tunnel where Wheeling and Lake Erie R. R. passes under.
19	1,116.00	Road crossing over Wheeling and Lake Erie R. R. one-half mile north of Greenough Station.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
20	1,093.30	Top of rail opposite Greenough Station on Wheeling and Lake Erie R. R.
21	1,063.10	Road crossing over Wheeling and Lake Erie R. R. one-half mile south of Greenough.
22	1,013.50	B. M. painted on base of Wheeling and Lake Erie R. R. trestle bridge "192 A."
23	1,181.70	B. M. on stone at southwest corner of culvert at crossroads in Snyder oil field.
24	1,018.40	B. M. painted on northwest post of bridge over stream flowing south near white house on hill.
25	1,053.00	B. M. on top of south rail of bridge over stream near crossroads.
26	1,212.00	B. M. painted on west end of culvert at forks of roads from Hopedale to Millers Station and Cadiz Junction. Marked 1222. Elevation doubtful. Made by Wetzel from Parman, 1209.3.
27	1,079.25	Floor of bridge over headwaters of Cross Creek on road from Hopedale to Falks.
28	1,048.00	Floor of bridge over headwaters of Cross Creek on road from Hopedale to Cadiz Junction.
29	**1,099.27**	Copper tablet sunk in top stone of north side wall of turntable at Cadiz Junction.
30	1,225.58	Top of rail on Cadiz Branch R. R. at road crossing at Falk Station.
31	1,009.55	B. M. painted on floor of bridge No. 184, Wheeling and Lake Erie R. R.
32	1,036.01	B. M. cut on northwest wall of overhead bridge of Wheeling and Lake Erie R. R. under Pittsburg, Cincinnati, Chicago and St. Louis R. R.
33	1,053.93	B. M. of Pennsylvania R. R. on bridge No. 73. Elevation by Pennsylvania R. R., 1052.79.
34	1,111.93	B. M. painted on top of bolt on southeast corner of overhead bridge of Wheeling and Lake Erie R. R.
35	1,072.00	Floor of bridge by oil well in Jewett field.
36	958.20	Floor of bridge over Hurford Creek, one and a half miles north of Hurford Station.
37	990.2	B. M. painted on rock at forks of road.
38	1,019.1	B. M. painted on iron bridge over Hurford Creek at crossroads near schoolhouse.
39	1,071.2	Elevation of ground at junction of roads on Hurford Creek by house.
40	1,064.80	Center of grass plot at junction of roads by church.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
41	1,096.5	Floor of bridge with stream flowing east one mile south of Hopedale.
42	1,117.4	Floor at the southwest corner of bridge at the south end of Hopedale.
43	1,262.00	Ground at intersection of roads in sec. 1, T. 1 N., R. 4.
44	1,018.70	Coping of east abutment of wood truss bridge over Piney Fork Creek.
45	1,156.90	B. M. painted on stone at southwest corner of crossroads York.
46	1,245.22	Ground at forks of roads, three-quarters of a mile north of York.
47	1,189.60	B. M. on stake at foot of guideboard, Smithfield, Mount Pleasant, and Portland.
48	973.00	Southwest corner of abutment of bridge over Piney Fork Creek at Southerland's mill.
49	1,008.50	B. M. painted on southeast abutment of iron bridge one mile south of Smithfield.
50	1,035.3	B. M. painted on southeast wing wall of iron bridge seven-tenths of a mile south of Smithfield.
51	**1,240.08**	Aluminum tablet sunk into the northwest water table of brick schoolhouse at Smithfield, marked 1240, Steubenville.
52	1,255.00	Ground in center of road at entrance to cemetery at north end of Smithfield.
53	1,260.30	Ground at junction of roads near schoolhouse No. 9. Guide-board; 5 miles to Bloomfield.
54	1,169.2	B. M. on rock east side of road by white house 3 miles north of Smithfield on Smithfield-Bloomfield road.
55	1,018.40	B. M. painted on northwest wing wall of bridge over Big McIntyre Creek on Smithfield-Bloomfield road.
56	1,092.30	Ground opposite watering trough at brown house on hill north of Big McIntyre Creek.
57	991.60	Northeast abutment of bridge over Piney Forks Creek on Smithfield-Cadiz road.
58	1,127.00	Ground on summit of hill in front of white house.
59	1,177.60	Ground at foot of guidepost at forks of roads 1½ miles west of Smithfield.
60	1,231.00	Foot of guidepost at forks of road three-fourths of a mile west of Smithfield.
61	1,233.30	B. M. on west end of culvert 1 mile east of Smithfield on ridge road.
62	1,120.30	Ground in center of road in front of house in pines on road north from Smithfield.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
63	829.14	R. R. B. M. on northeast coping stone of arch bridge No. 53 over Cross Creek, 300 feet east of Reeds Station.
64	837.12	R. R. B. M. on northeast coping stone arch bridge over Cross Creek 900 feet west of Reeds Station.
65	845.50	R. R. B. M. on northeast coping stone of bridge No. 55.
66	**844.29**	Copper tablet sunk in northeast coping stone of bridge No. 56 of Pittsburg, Cincinnati, Chicago and St. Louis R. R. over Cross Creek. Marked 844 Steubenville.
67	865.79	B. M. cut on top stone of northwest wing wall of iron wagon bridge at Skelley Station.
68	**1,298.26**	Aluminum tablet sunk in northwest water table of schoolhouse at Bloomfield. Marked 1298 Steubenville.
69	1,222.92	Ground at intersection of roads one-half mile northeast of Bloomfield.
70	1,196.07	Ground at intersection of roads 1½ miles northeast of Bloomfield.
71	1,180.00	Ground at intersection of road to Skelley and ridge road south of railroad.
72	969.00	B. M. painted on northwest corner of wing wall of bridge abutment over Big McIntyre Creek at Tunnel Mill schoolhouse.
73	920.50	B. M. painted on northwest corner of abutment of bridge over McIntyre Creek at Southerlands Mill.
74	1,184.50	Ground at crossroads 1 mile from Southerlands Mill toward Bloomfield.
75	1,222.00	B. M. painted on root of oak tree in triangular grass plot at intersection of roads.
76	1,245.00	B. M. painted on west end of box culvert at cross roads to New Alexander and Bloomfield.
77	1,276.00	Ground at foot of guidepost at forks of road 1½ miles east of Bloomfield—Bloomfield-Loftus road.
78	1,087.40	Floor of bridge on road from Skelley to Opossum Hollow.
79	993.80	B. M. painted on stone by gate to low white house in Opossum Hollow.
80	995.33	B. M. painted on rock by gate to yellow house in Opossum Hollow.
81	1,030.80	Ground at cross roads three-fourths mile southwest of Reeds Station.
82	853.00	Ground at bend in road east of stream crossing in Opossum Hollow.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
83	1,174.00	Junction of roads south of Opossum Hollow.
84	1,246.70	Ground at summit in short turn of road southwest of Loftus crossing.
85	1,226.60	Ground at intersection of roads south of Loftus crossing.
86	1,124.57	B. M. on step to white church near schoolhouse near Slab Run.
87	1,136.87	Ground at foot of post opposite lane in negro settlement.
88	1,251.90	Ground at road turning south from mud pike one-half mile west of Bloomfield.
89	1,271.70	B. M. on stepping in front of house at intersection of mud pike and road to Unionport.
90	1,294.60	Ground in center of road in front of white house.
91	1,352.94	Ground under Hopedale triangulation signal.
92	1,224.60	B. M. on white limerock 300 feet south of Memorial Church.
93	1,235.60	B. M. on root of tree at intersection of roads 2 miles southwest of Bloomfield.
94	1,108.90	B. M. marked on stone at end of sluice at intersection of roads.
95	1,150.30	B. M. cut on log at mail box at intersection of roads.
96	888.73	B. M. cut on southwest coping stone of bridge No. 58 of Pittsburg, Cincinnati, Chicago and St. Louis R. R. over Cross Creek nine-tenths mile west of Skelley Station.
97	900.41	R. R. B. M. northeast coping stone bridge No. 59, at west end of tunnel No. 7, 1 mile west of Skelley.
98	912.54	B. M. on northwest wing wall of wagon bridge at Bloomfield Station.
99	926.54	R. R. B. M. on northeast coping of stone bridge No. 61, at east of tunnel No. 8.
100	937.10	R. R. B. M. on northeast coping of bridge No. 62, six-tenths mile west of Bloomfield.
101	953.95	R. R. B. M. on northeast coping stone of bridge No. 64, 1 mile west of Bloomfield.
102	961.99	R. R. B. M. on northeast coping stone of bridge No. 65, 1 mile west of Bloomfield.
103	976.31	Aluminum tablet sunk in northeast coping stone of bridge over Cross Creek, 1,200 feet west of Unionport Station. Marked 976 Steubenville.
104	978.86	R. R. B. M. on northeast coping stone of bridge No. 67, west of Unionport.
105	983.83	R. R. B. M. on northeast coping stone of bridge No. 68, 1½ miles west of Unionport.
106	876.23	Floor of bridge over stream near Willow Grove schoolhouse, one-half mile north of Skelley Station.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
107	1,223.78	B. M. painted on rock 60 feet north of brick house west side Skelley-Richmond road.
108	1,206.37	B. M. painted on rock at entrance to cemetery, Skelley-Richmond road, 3½ miles north of Skelley.
109	1,241.60	Ground on summit at entrance to house 1 mile south of Richmond.
110	1,163.49	B. M. painted on southwest abutment of bridge, Skelly-Richmond road, one-half mile south of Richmond.
111	1,185.83	Aluminum tablet sunk in stone step of brick schoolhouse at the south end of Richmond, marked 1286 Steubenville.
112	1,276.70	Ground at intersection of roads at Fairfield.
113	1,287.93	B. M. marked on east end of culvert at road north one-half mile west of Fairfield.
114	1,302.49	B. M. painted on nail in bridge at road south from pike 3½ miles west of Richmond.
115	904.00	Elevation of bridge at Reeds Mills. New bridge since B. M. made; elevation thought to be about the same.
116	1,190.90	Ground in center of road opposite yellow house on road between Reeds Mills and Richmond.
117	1,041.58	Floor of bridge over stream.
118	872.33	B. M. painted on floor of bridge over small stream near old mill on Town Fork.
119	914.15	Floor of bridge over Town Fork on road from Richmond to Shane post-office.
120	1,137.34	Floor of bridge on Richmond and Steubenville pike 1½ miles east of Richmond.
121	1,140.26	Intersection of roads on ridge between Richmond and Bloomfield station.
122	1,086.00	Floor of bridge on small stream on Richmond-Salem road 2 miles from Richmond.
123	1,058.00	Floor of bridge on Richmond-Salem road 3 miles from Richmond.
124	1,057.00	Floor of bridge on Richmond-Salem road 1 mile east of Salem.
125	1,160.70	Ground at intersection of roads 1 mile east of Salem.
126	1,126.43	Ground at intersection of roads one-half mile south of Salem.
127	962.70	Floor of bridge over large stream on Unionport and Richmond road.
128	997.00	Floor of small wooden bridge on Carman Hopedale road.
129	1,045.70	B. M. on stump in front of barn on Carmen Hopedale road.
130	1,272.70	Ground at intersection of mud pike and road to Carman.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
131	1,221.27	Ground at foot of post holding sign for sale of coal at intersection of mud pike and county line road.
132	1,292.00	Ground at foot of fence post at northeast corner of intersection of mud pike and ridge road to Unionport.
133	1,251.00	B. M. painted on culvert at private road to west from ridge road from mud pike to Unionport.
134	1,314.30	Middle of road at summit on ridge road to Unionport.
135	1,206.40	Middle of roads at forks on hill south of Unionport.
136	1,178.50	B. M. on stump at forks of section-line road and Bloomfield and Unionport road.
137	1,013.90	Floor of bridge on Bloomfield and Unionport road.
138	1,218.80	Ground in road in front of white house on hill south of Unionport.
139	....	
140	1,289.10	B. M. cut in southeast curbstone at corner of streets in center of town of Jefferson.
141	1,169.37	B. M. painted on southeast corner stone of bridge one-half mile south of Jefferson toward Jewett.
142	1,094.20	Floor of small bridge by old sawmill $1\frac{1}{3}$ miles south of Jefferson toward Jewett.
143	1,079.54	B. M. painted on northeast corner of stone bridge 2 miles south of Jefferson toward Jewett.
144	1,046.53	B. M. painted on rock covering spring at crossroads near schoolhouse $2\frac{1}{2}$ miles south of Jefferson toward Jewett.
145	1,034.27	B. M. painted on northwest corner of stone bridge $2\frac{8}{10}$ miles south of Jefferson toward Jewett.
146	1,031.34	Floor of bridge near flour mill at intersection of roads 3 miles south of Jefferson toward Jewett.
147	1,032.49	B. M. painted on rock at intersection of roads 1 mile from Jewett toward Jefferson.
148	1,183.48	Ground at intersection of roads over tunnel on Pittsburg, Cincinnati, Chicago and St. Louis R. R. west of Cadiz Junction.
149	1,208.60	Top of section stone in crossroads by brick church.
150	1,139.45	Floor of small bridge on Jefferson-Cadiz Junction road 1 mile south of Jefferson.
151	1,271.49	B. M. painted on stone at forks of roads from Jefferson to Cadiz Junction and Millers station.
152	1,112.80	B. M. painted on top of watering trough opposite house $1\frac{1}{2}$ miles east of Jefferson on Jefferson and Millers station road.
153	1,076.68	B. M. painted on northwest corner of bridge at road north 2 miles east of Jefferson.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
154	1,055.58	B. M. painted on bridge.
155	1,041.55	B. M. on top of stepping-stone in front of brown house near crossroads.
156	1,252.00	B. M. painted on stone at southwest corner of schoolhouse at road intersection 1 mile north of Millers station.
157	....	
158	1,022.27	R. R. B. M. on northeast corner of bridge No. 71, Pittsburg, Cincinnati, Chicago and St. Louis R. R., 600 feet west of Millers station.
159	....	
160	1,086.54	B. M. painted on bridge in woods on road from Richmond to Shane post-office at foot of first hill from Richmond.
161	**1,331.08**	Aluminum tablet sunk in southeast corner foundation stone of public school building at East Springfield, marked 1331, Steubenville.
162	1,337.00	Ground on summit at road to right from Ridge road, 1 mile north of East Springfield.
163	1,215.21	Floor of small bridge on Ridge road 1½ miles north of East Springfield.
164	1,309.00	Ground in middle of road opposite church, one-third of a mile south of Circle Green post-office.
165	1,302.00	Ground in middle of road opposite Circle Green post-office.
166	1,277.00	Ground on summit of road by schoolhouse on North Ridge road.
167	1,062.38	Floor of bridge over stream on road from Circle Green post-office to Middle Ridge.
168	1,152.82	Floor of bridge over small stream near schoolhouse on Middle Ridge road.
169	1,154.77	Ground at intersection of roads on ridge north of Hildebrand Creek.
170	1,008.00	Floor of iron bridge over town fork of Yellow Creek.
171	1,228.87	Ground at crossroads near church, 1½ miles northeast of stone post-office.
172	879.56	Floor of bridge over Hildebrand Creek.
173	1,148.00	Floor of bridge over Wolf Creek eight-tenths of a mile northwest of East Springfield.
174	1,046.17	B. M. painted on bridge $1\frac{7}{10}$ miles northwest of East Springfield.
175	**905.45**	Copper tablet sunk into southwest wing wall of iron bridge over Yellow Creek, 2 miles north of Amsterdam.
176	933.90	Floor of iron bridge on Main street in the town of Amsterdam.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
177	**1,275.96**	Aluminum tablet sunk into top foundation stone on north side of schoolhouse 3 miles south of Amsterdam on Amsterdam-Jefferson Ridge road.
178	1,307.00	Ground at foot of guideboard at forks of road 3½ miles south of Amsterdam.
179	1,291.47	Ground in road where private road west leaves 4 miles south of Amsterdam.
180	1,159.56	B. M. painted on small bridge 5 miles south of Amsterdam.
181	1,144.07	B. M. painted on northeast wing wall of bridge at foot of hill east of Jefferson.
182	1,365.60	B. M. on top of marking stone under Jefferson triangulation signal.
183	1,241.57	Ground at road to west from Jefferson-Kilgore road 1½ miles north of Jefferson.
184	1,260.00	Ground at summit opposite large oak tree on Jefferson-Kilgore road 3 miles north of Jefferson.
185	1,254.00	Ground at summit near private road to east.
186	963.97	Floor of iron bridge 1 mile south of Amsterdam on Kilgore-Amsterdam road.
187	965.83	Floor of wooden bridge south of blacksmith shop.
188	984.00	Floor of iron bridge on Amsterdam and Jefferson Valley road 1½ miles south of Amsterdam.
189	1,002.00	B. M. painted on bridge over small stream 2 miles south of Amsterdam.
190	1,246.72	Ground at summit near intersection of roads on section lines.
191	1,046.49	B. M. painted on stone arch bridge 1½ miles north of Kilgore.
192	1,024.31	Top rail of iron bridge near schoolhouse at intersection of roads north of Kilgore.
193	1,334.07	Ground at foot of post with flag at cemetery on top of hill.
194	1,051.39	B. M. painted on stone at private road to right.
195	1,122.54	Floor of bridge three-fourths of a mile east of Kilgore—Kilgore-Amsterdam road.
196	1,065.23	Floor of bridge on county line road short distance south of Salem.
197	1,251.10	Ground in road at short turn to left on Salem to Millers Station road, 1 mile from Salem.
198	1,075.96	Floor of bridge on Salem-Miller road.
199	1,255.50	Ground at intersection of roads.
200	1,235.47	B. M. painted on pump bed at schoolhouse.

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PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Bulletin No. 198.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of the United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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